POWER PLANT ENGINEERING

Established Over 32 Years

VOL. XXXII CHICAGO, MAY 15, 1928 No. 10

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port the racks, and, consequently, the whole floor of bars, which are removed by turning the spindle of the pinnion *c*, of which there are two, one at each end of the spindle, so as to operate upon both sides of the grating at once. When a floor of bars has become foul, a clean floor is attached to it, as partly shown by the hooked joint at *g*, by which, as the foul floor is drawn out, the clean one is drawn in.

A patent for improvements in boilers for locomotive engines was obtained by Mr. James Frazer, on the 7th May, 1833, upon the basis of which it is said he constructed a steam carriage, but of the completion or performance of which we are at present uninformed. Annexed is a transverse section of the boiler; the fire-place is at *a*, and the smoke, &c. is conveyed through an eccentrically-curved tube *b b*, imparting its heat to the surrounding water, in its progress to the chimney. There are cross pipes, which pass quite through the flue-tube at various places, as shown by the dotted lines, that the circulation of the water or passage of the steam may not be impeded. The patentee has included in his patent some other modifications of his plans, wherein a great number of small flue-tubes are used to distribute the heat throughout the water, and to serve as supports to the fire-place and flues.

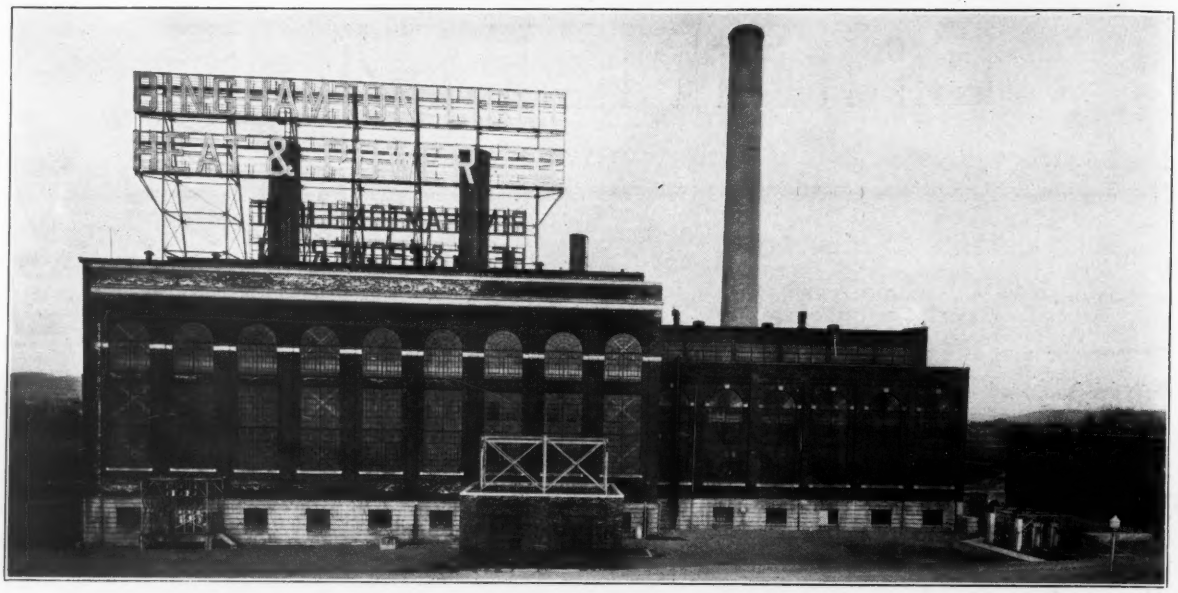
Ye Olde Water-Cooled Furnace

ON A BRIGHT May morning, in the year of our Lord, 1833, one James Frazer, subject of His Gracious Majesty George IV and by the grace of God owner of one steam carriage, Model 7 (the model tells the speed), betook himself unto his back yard to view with disgust his sole possession.

Good paint job, good engine, genuine leather and all that, but last year's model—small boiler and no speed. Just the night before, on his way to a night club, a certain Robert Stevenson (not the one named after the link that made the locomotive famous) driving one of the new fangled locomotive engines passed Mr. Frazer at the terrific speed of 11 mi. an hour.

Immediately, Mr. Frazer designed a bigger and better boiler, to drive his carriage at the unheard of speed of 15 mi. an hour and so beat Mr. Stevenson at his own game. The boiler he designed, shown above, was described and illustrated by Luke Hebert in his book, "Engineers and Mechanics Encyclopaedia," published by Thomas Kelly of London in 1836 and now in the possession of Otto Kaad, noted collector of rare volumes.

In those days, before Colin Kelley, of brick yard fame, sold engineers the idea of refractory lined furnaces, water cooled furnaces were all the rage. Modern engineers are, however, again getting away from solid refractory walls and the use of water cooled furnaces is increasing. Some of the methods now used in tying these water walls into modern boiler systems are described in this issue.



Binghamton Station Adds 30,000-Kw. Unit

BINGHAMTON STATION, STARTED IN 1916 WITH 5500 KW., ADDS THREE PULVERIZED COAL-FIRED BOILERS AND A NEW 30,000-KW. TURBO-GENERATOR

IN 1916, WHEN THE Binghamton Station was built near Binghamton, N. Y., two generating units were installed, one of 2000-kw. and the other of 3500-kw. capacity. At that time the load possibilities did not seem particularly promising and these machines were considered adequate for several years to come. The installation had hardly been completed, however, before more generating capacity was needed and two more boilers were installed with a new 5000-kw. generator. About a year later, a 2500-kw. generator was installed.

In 1922 more steam capacity was needed so a new boiler was added to assist in carrying the station over the winter peak. As there was no space available in the buildings, and no time to complete a new extension to the building, this boiler was installed outside. A rough shelter of wood was constructed to protect the new boiler from the weather and the unit operated in this manner until the new addition was constructed in 1923.

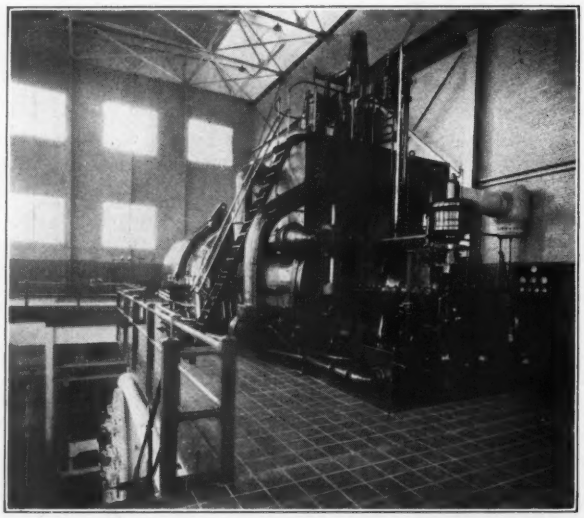


FIG. 1. STEAM END OF THE NEW 30,000-KW. TURBO-GENERATOR

In 1923, the load was growing rapidly and this time a 10,000-kw. turbine was installed and the new addition to the building was made higher and wider than the original structure to accommodate the larger sized equipment. At the same time, a 1259-hp. single-pass Edge Moor boiler for 300-lb. pressure was installed. This boiler, the seventh unit, was the first commercial Edge Moor single-pass unit and it was the first unit in the station to be fired by pulverized fuel, using eight 6-in. burners. The furnace was the first of the Detrick air-cooled, hung-wall type to be placed in operation. It was the successful operation of this boiler on pulverized coal that led to the adoption of this system of fuel burning for all future units. The 10,000-kw. turbine, although designed for 285-lb. pressure, was nozzled for 185 lb. All boilers at this time operated at 200 lb. pressure and it was intended that later the pressure on the new boilers would be raised and reducing valves installed between the old and the new units. Valves and desuperheater equipment were purchased but were not installed at the time.

THE 1927 ADDITION

The 10,000-kw. turbo-generator, in spite of its being twice the size of the next largest unit, was not destined to hold supremacy long and in 1926 work was started on another addition to the station which was completed in the latter part of 1927. This addition was by far

the largest and added more capacity than the combined capacity of all the previous units, since it consisted of a 30,000-kw. turbo-generator together with three new boilers. This article is concerned with the engineering features of this section. In order to give the reader a correct idea of the installation, there will be presented first a few facts regarding the plant as a whole.

Binghamton Station is located on the Susquehanna River about four miles west (downstream) of Binghamton, N. Y. It is owned by the Binghamton Light, Heat and Power Co. and is managed by W. S. Barstow & Company, Inc., who were also the designers and builders. The station now has a total generating capacity of 53,000 kw., all of which is used locally, as the system is not interconnected with other power systems.

The architecture of the building, while not ornate, is attractive, as can be seen from the exterior view, shown at the head of this article. The exterior is faced with red pressed brick with white stone trimming. One end of the station is provided with a temporary wall, since it is expected that additional capacity will be required and the building will be extended at this end. Coal is delivered direct by railroad cars from a convenient siding and the plant's location on the banks of the Susquehanna River insures ample condensing water for a capacity considerably greater than that installed at present.

A section through the new part of the station, showing the arrangement of the equipment, is shown in Fig. 2. This shows the new 30,000-kw. turbo-generator known as Unit No. 6, and boiler unit No. 9. The new boiler equipment added consisted of three units, a Connelly boiler and 2 Edge Moor boilers, designated respectively as units 8, 9 and 10.

Boiler No. 8 is a 1062-hp., class T-35, four-drum, bent tube, Connelly unit, with integral, water-cooled bridge wall. It is baffled for three passes and is provided with an Elesco superheater designed to give 700 deg. F. total temperature at 400 lb. gage pressure and at a rating of 100,000 lb. of steam per hour. The boiler has 10,620 sq. ft. of heating surface and is designed for 450 lb. gage working pressure but is operated at 400 lb. pressure.

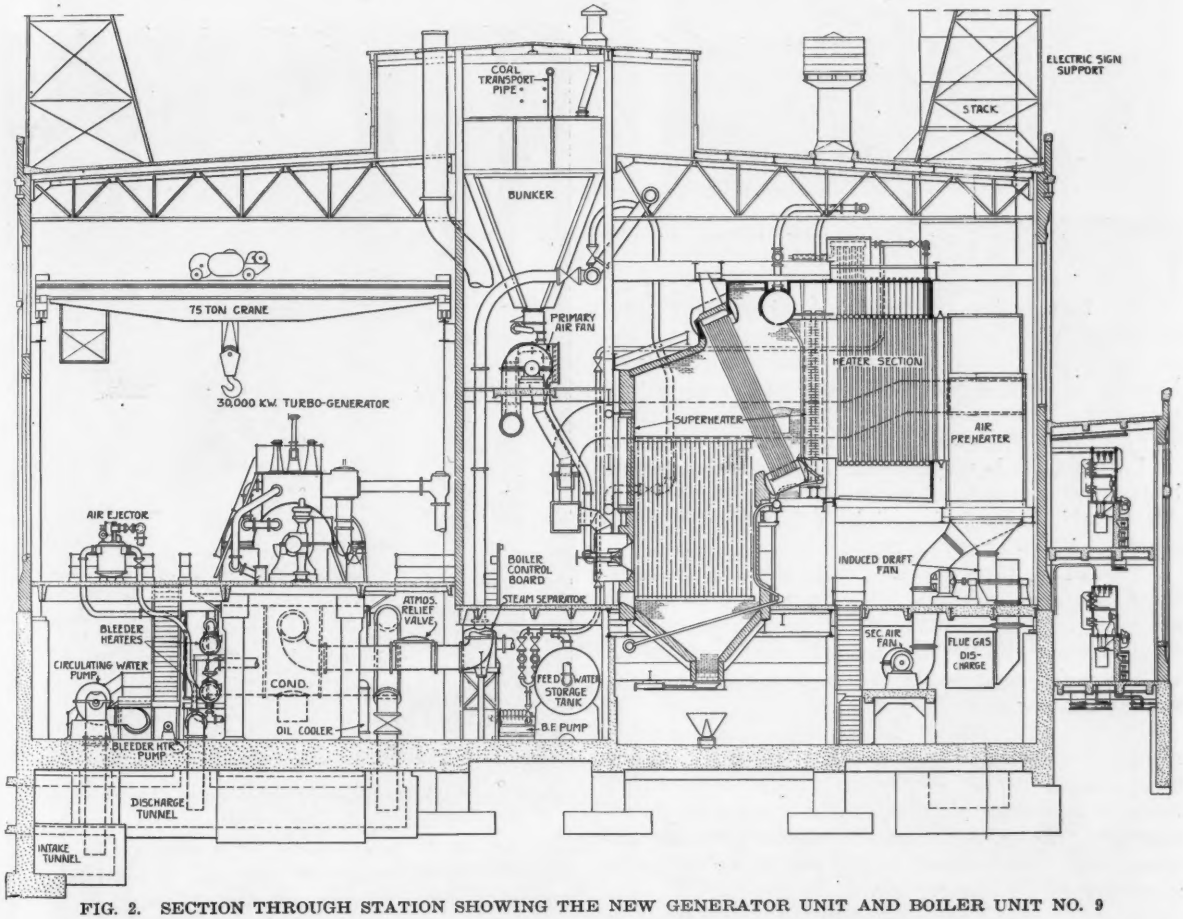


FIG. 2. SECTION THROUGH STATION SHOWING THE NEW GENERATOR UNIT AND BOILER UNIT NO. 9

This boiler is provided with a Foster steel-tube economizer having 9180 sq. ft. of surface. This, it will be noted, is an extremely large percentage of economizer surface to boiler heating surface, over 85 per cent.

The furnace has Detrick arches and walls, Bailey water bottom and a water-cooled bridge wall and is fired by means of seven 8-in. Fuller burners.

This unit was designed for 100,000 lb. of steam per hour, maximum, with the present furnace but it is planned to install water walls and larger induced draft fans so that the future output will be 150,000 lb. per hr.

Boilers No. 9 and 10 are both Edge Moor single-pass boilers rated at 987 hp. and designed for 450 lb.

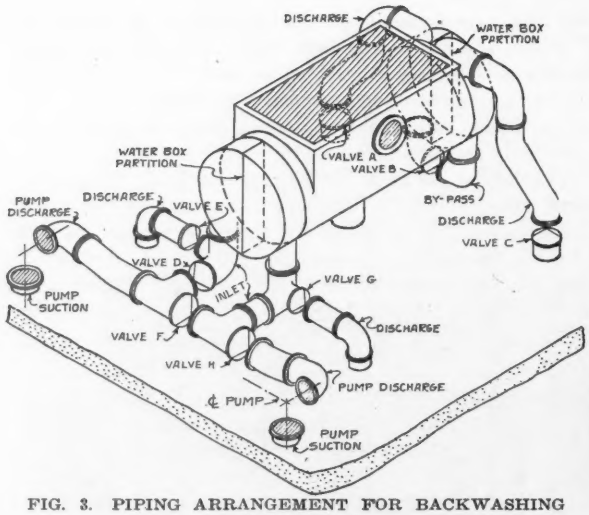


FIG. 3. PIPING ARRANGEMENT FOR BACKWASHING CONDENSER

pressure. No. 9 has a Foster combination radiant and convection type superheater designed to raise the steam temperature to 725 deg. F.

The furnace has Combustion Engineering Co. fin-tube water walls on three sides and a Combustion Engineering Co. water screen at the bottom. Air for combustion is heated by means of a Combustion plate type air preheater having a total of 12,000 sq. ft. of surface. The unit is fired by two Couch burners.

Unit No. 10 has Bailey water walls and a hopper bottom and is fired by three Calumet intertube burners. Air for this boiler is heated in a Sturtevant air preheater of 12,000 sq. ft. surface.

Each of the three new boilers is served by two Sturtevant induced draft fans. Boiler No. 8 fans are designed to handle 33,760 cu. ft. of flue gas per min. at 6.1-in. water static pressure and 425 deg. F. Fans for units 9 and 10 are rated at 46,000 c.f.m. at 6.5-in. water static pressure and 420 deg. F.

Primary air for boiler No. 8 is taken from the boiler room while on boilers Nos. 9 and 10 arrangement has been made to temper the room air with preheated air from the secondary air ducts. A recent change in arrangement enables the operators to shut down the primary air fans on boilers 9 and 10 and to use preheated secondary air as primary air.

Boiler feedwater is supplied to the boilers by three 400-g.p.m., 525-lb. pressure, 8-stage, Allis-Chalmers boiler feed pumps, two driven by 250-hp. motors and the third turbine driven. Feedwater level is controlled

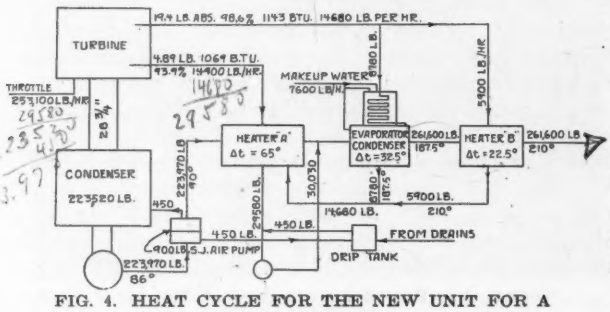


FIG. 4. HEAT CYCLE FOR THE NEW UNIT FOR A 26,000-KW. LOAD

on boiler No. 8 by two Stets regulators and on units Nos. 9 and 10 by a combination of a Mercon differential pressure regulator and a Stets feedwater regulator. The Mercon regulator is arranged to maintain a constant drop of 25 lb. across the Stets regulator.

Coal Preparation and Handling

The coal preparation and transport system is best described by reference to Fig. 7, which shows the arrangement of equipment schematically. The central system of pulverizing is used. Coal, after being weighed, is delivered into raw coal bunkers located just above the dryer. The latter is a horizontal rotary unit, 6 ft. in

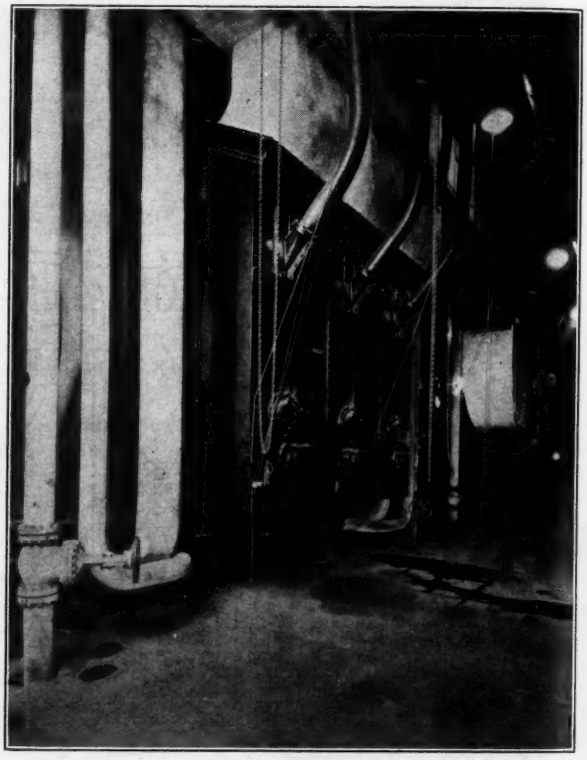


FIG. 5. BOILER NO. 10 SHOWING THE CALUMET BURNERS

diameter, 42 ft. long, heated by a separate hand-fired furnace. From the dryer, the coal is elevated to a bunker set directly over three 46-in. screen type Fuller mills. Two of these mills were installed in 1923 when the first pulverized coal-fired boiler was put in, and the third was installed as a part of the 1927 extension. From the mills, pulverized coal is carried by a screw conveyor to 6-in. and 8-in. Fuller Kinyon pumps, which deliver it through the coal transport line to the boiler room, where it is stored temporarily in the pulverized coal bunkers over boilers 7, 8, 9 and 10.

Figure 2 shows the arrangement of these pulverized coal bunkers, also the location of the primary air fans. Pulverized coal is taken from the bottom of the bunkers and delivered to the burners by either Bailey or Fuller coal feeders, depending upon the particular boiler unit. Primary air is introduced at the feeders, as shown in Fig. 2.

There are three primary air fans and four secondary air fans, all of the Sturtevant turbovane design. One

Views of New Equipment at Binghamton Station

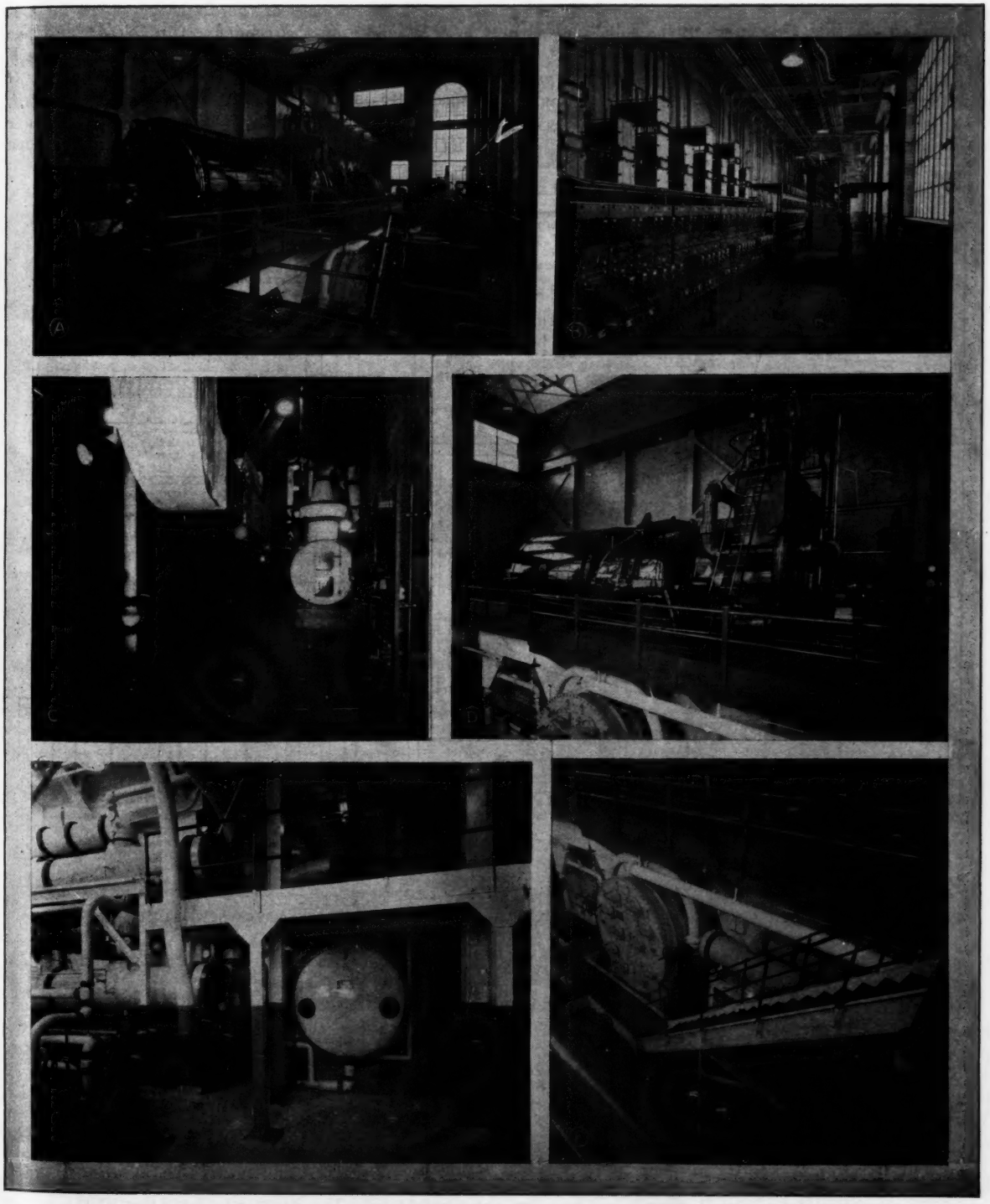


Fig. 6. A. General view of turbine room, showing new 30,000-kw. unit in the foreground. B. Some of the automatic contactor panels for controlling station equipment. C. In the boiler room, showing one of the feedwater heaters at the right. D. Another view of the new unit. E. The evaporator and some of the heaters on the condenser floor. F. End view of the 22,000-sq. ft., single-pass condenser. This has a special arrangement of piping for cleaning and backwashing.

of the primary air fans has a capacity of 16,000 c.f.m. at 9-in. static pressure and the other two have capacities of 9500 c.f.m. at 11.5-in. static pressure.

All four of the secondary air fans are alike, being rated at 26,000 c.f.m. at 7.5-in. static pressure. The secondary air fans, as well as the induced draft fans, are located below and at the rear of the boilers, as may be noted from Fig. 2.

Ash is removed from the hoppers through ash gates as indicated on the drawing, into ash cars running on tracks below. The ash gates were manufactured by the Allen-Sherman-Hoff Co.

the water boxes. Normally, valves G and E on the head end of the condenser are closed, as is also valve B on the rear end. The flow then is simply from one end of the condenser to the other. After the condenser has been in operation for some time and it becomes necessary to backwash, both of the discharge valves (A and C) at the rear of the condenser are closed and the bypass valve B is opened. At the same time the valve F at the head end is closed and one of the valves E or G opened. By manipulating the valves in this manner, the condenser becomes a two-pass condenser, the water going into one water box, passing to the rear, then

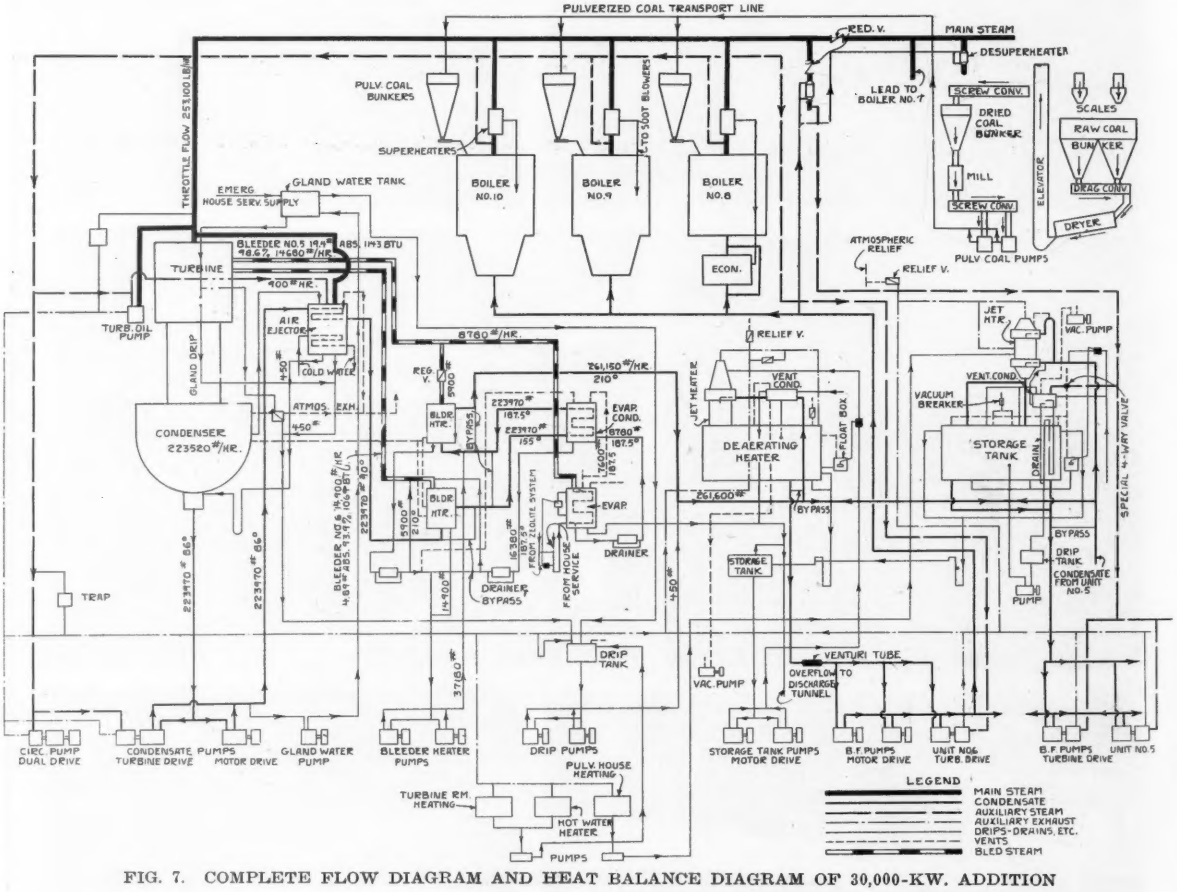


FIG. 7. COMPLETE FLOW DIAGRAM AND HEAT BALANCE DIAGRAM OF 30,000-KW. ADDITION

New Generator Unit Has Novel Condenser Piping Arrangement

Generating unit No. 6, the new 30,000-kw. machine, has a 35,295-kv.a. generator direct connected to an impulse-reaction, single-cylinder turbine operating at 1800 r.p.m. It is mounted with its shaft parallel to the length of the turbine room, and is served by a C. H. Wheeler, 22,000-sq. ft., single-pass condenser with vertically divided water boxes. The tubes in this unit are ⅞-in. O. D. of No. 17 B. W. G. Admiralty metal. It is served by two 18,000-g.p.m. circulating water pumps, two 550-g.p.m., two-stage hotwell pumps and two two-stage Radojet air pumps.

An interesting feature about the condenser is the piping arrangement provided for cleaning and backwashing. This is shown isometrically in Fig. 3. The piping, it will be noted, is symmetrical with respect to through the bypass valves between the water boxes and returning to the head end.

Thus the back-washing operation is accomplished without shutting the unit down and without any decrease in capacity. This system has worked out very nicely and except for a slight momentary decrease in vacuum while the valves are being manipulated, no disturbing effects are noted. The back washing procedure is repeated for each half of the unit. The valves controlling this back washing arrangement are operated by electric motors and are all controlled from a central control board. This makes the operation of the system extremely simple.

Condensing water is Susquehanna River water drawn through a covered intake tunnel by the circulating pumps. The circulating water installation is somewhat unusual in that the water screen house is located

Principal Equipment in 1927 Extension to Binghamton Station of Binghamton Light, Heat & Power Company

General

Location.....
Susquehanna River, about 4 mi. west (downstream) of Binghamton, N. Y.
Character of Service.....
.....Central Station (isolated)
Capacity before extension.....23,000 kw.
Capacity new unit.....30,000 kw.
Designed and built by.....
.....W. S. Barstow & Co., Inc.

Boilers and Settings

2 Edge Moor Iron Company single pass, 4 unit, 9876 sq. ft. boilers designed for 450 lb. gage working pressure.
1 D. Connelly Boiler Co. 4-drum bent tube, 10,620 sq. ft. boiler designed for 448 lb. gage working pressure, and integral water cooled bridge wall.
1 Foster Wheeler Corp. Foster economizer, 9180 sq. ft. external heating surface.
1 Superheater Co. — Elesco Superheater designed to give 700 deg. F. total steam temperature at 400 lb. gage pressure and a rating of 100,000 lb. steam per hr.
1 Foster Wheeler Corp.—Foster combination convection and radiant heat superheater designed to give 265 deg. F. superheat or a total temperature of 725 deg. at 450 lb. gage pressure and a rating of 150,000 lb. steam per hr.
1 Edge Moor Iron Co. convection superheater designed to give 725 deg. F. total steam temperature at 450 lb. gage pressure and a rating of 150,000 lb. steam per hr.
1 Boiler setting with M. H. Detrick Co. air cooled side walls.
3 M. H. Detrick Co. furnace arches.
1 Fuller Lehigh Co. Bailey water cooled furnace floor.
1 Combustion Engineering Co. fin tube, water wall furnace with two Couch burners.
1 Fuller Lehigh Co. Bailey water wall furnace with three Calumet intertube burners.
Ash gates by.....Allen-Sherman-Hoff Co.
Air preheaters .....
B. F. Sturtevant Co. and Combustion Engineering Corp.

Miscellaneous Boiler Fittings

Safety valves—boiler and superheaters .....Crosby Steam Gage & Valve Co.
Safety valve—economizer.....
.....Consolidated Safety Valve Co.
Blowoff valves .....
Yarnall-Waring Co., Everlasting Valve Co. and Edward Valve & Mfg. Co.
Soot-blowers .....
....Diamond Power Specialty Company
Water columns .....
Reliance Gauge Column Co. & Edge Moor Iron Co.
Feedwater regulators .....
The Mercon Regulator Co. and The Stets Co.
1 Tracyfier by Andrews-Bradshaw Co.

Fuel Supply

Fuel—bituminous slack
Raw coal handling equipment.....
.....Jeffrey Mfg. Co.
Rotary dryer.....Fuller Lehigh Co.
Pulverizer Mills .....
Fuller Lehigh Co. 46-in. Screen Type Mills.
2 Fuller-Kinyon coal pumps.....
.....Fuller Lehigh Co.
Fuller-Kinyon coal transport line.....
.....Fuller Lehigh Co.
5 Bailey coal feeders..Fuller Lehigh Co.
7 3-in. Fuller screw type coal feeders.
.....Fuller Lehigh Co.
1 B. F. Sturtevant Co.—No. 80 Turbovane, Design 4, double width, double inlet primary air fan driven by 50 hp. Allis-Chalmers Mfg. Co., 2200 v., 1750 r.p.m., squirrel cage induction motor. The capacity at 9 in. water static pressure is 16,000 c.f.m.
2 B. F. Sturtevant Co.—No. 85 special turbovane design 4, single width, single inlet primary air fans driven by 40 hp. Allis-Chalmers Mfg. Co. type AR 2200 v., 1750 r.p.m., squirrel cage induction motors. The capacity at 11.5 in. water static pressure is 9500 c.f.m.
4 B. F. Sturtevant Co. No. 80 turbovane, design 5, double width, double inlet, secondary air fans driven by 50 hp. Allis-Chalmers Mfg. Co. type AR 2200 v., 1750 r.p.m., squirrel cage induction motors. The capacity at 7.5 in. water static pressure is 26,000 c.f.m.

Draft Equipment

1 12 ft. diam. brick lined, steel stack 145 ft. high by the Dover Boiler Works.
Boiler breechings and duct work for two boilers by the Dover Boiler Works.
Boiler breechings for one boiler by Connery & Co., Inc.
2 B. F. Sturtevant Co. No. 9 Multivane, design 3, single width, single inlet, overhung wheel type induced draft fans driven by 75 hp. Allis-Chalmers Mfg. Co. type A.R.Y., 2200 v., 870 r.p.m., wound rotor induction motors. Capacity at 6.1 in. water static pressure and 425 deg. F. flue gas is 33,760 c.f.m.
4 B. F. Sturtevant Co. No. 9 multivane, design 3, single width, single inlet, overhung wheel type induced draft fans driven by 125 hp. Allis-Chalmers Mfg. Co. type A.N.Y. 2200-v., 875 r.p.m., wound rotor induction motors. Capacity at 6.5 in. water static pressure and 420 deg. flue gas is 46,000 c.f.m.

Feedwater Pumps and Heaters

3 Allis-Chalmers Mfg. Co. type V. eight stage 4 in. discharge, 400 g.p.m., 525 lb. discharge pressure boiler feed pumps, two driven by 250 hp. Allis-Chalmers Mfg. Co. type AN, 2200 v., 1750 r.p.m., squirrel cage induction motors and one driven by a Terry Steam Turbine Co. 200 hp., 1750 r.p.m. steam turbine.
2 Ross Heater & Mfg. Co. turbine extraction feedwater heaters (one at 5.75 lb. abs. and one at 17 lb. ab. pressure), two pass, floating head, closed type, one designed to heat 261,850 lb. of water per hr. from 87 deg. to 158.1 deg. F., and the other designed to heat 297,200 lb. of water per hr. from 159.1 deg. to 213 deg. F.
1 Griscom-Russell Co. No. 5-S-144 horizontal bent tube evaporator of the scale shedding submerged type with a No. 31-156 style "L" four pass horizontal evaporator condenser. Capacity of the apparatus is 7600 lb. distilled water per hr. at 26,000 kw. load on turbine.
1 Cochrane cylindrical deaerating tray heater with jet heater head having a capacity of 400,000 lb. of feedwater per hr. Tank diam. 6 ft. and length 17 ft. Jet heater head 32 in. diam.

Turbo-Generator and Condensers

1 Westinghouse E. & M. Co. 35,000 kw. impulse reaction, single case turbine driving a 35,295 kva., 13,800 v., 3 phase, 60 cycle, 1800 r.p.m. generator with direct connected 120 kw., 250 v. exciter. Capacity of unit 30,000 kw. at 85 per cent power factor.
1 C. H. Wheeler Mfg. Co. 22,000 sq. ft. vertically divided water box single pass condenser with ⅞ in. O. D. No. 17 B. W. G. Admiralty Metal Tubes.
2 C. H. Wheeler Mfg. Co. TCA-90, two stage radojet air pumps.
2 C. H. Wheeler Mfg. Co. No. 6 Class C-550 g.p.m., two stage, hotwell pumps, one driven by a 40 hp. Allis-Chalmers Mfg. Co. 2200 v., 1150 r.p.m. squirrel cage induction motor and one by a 35 hp. Terry Steam Turbine Co. type "Z1," 1200 r.p.m. steam turbine.
2 Allis-Chalmers Mfg. Co. 24 in. type LS, single stage centrifugal pumps, each delivering 18,000 g.p.m. against 17 ft. head at 390 r.p.m., driven by two 125 hp. Allis-Chalmers Mfg. Co. type A. N. 2200 v., 390 r.p.m., squirrel cage induction motors and one 100 hp. Terry Steam Turbine Co. type E. 2430 r.p.m. steam turbine with reduction gearing.
1 Griscom-Russell Co. U-fin generator air cooler with a capacity of 80,000 c.f.m.

Miscellaneous Material and Equipment

Steel—approx. 950 t. Belmont Iron Works
Reinforcing steel for concrete—134 t...
.....E. T. Edwards, Columbia, Pa.
Stair treads and walkways.....
.....American Abrasive Metals Co.
Walkways.....Irving Iron Works
Windows and steel sash.....
.....Detroit Steel Products Co.
Ventilators.....H. H. Robertson Co.
Face brick—
Terra cotta—4500 cu. ft.....
.....Wilkesbarre Clay Products Co.
Floor tile.....Belfi Bros. & Co.
Lubricating oil purifier.....
.....DeLaval Separator Co.
Oil coolers.....Griscom-Russell Co.
High pressure steam gate valves.....
Reading Steel Casting Co. and The Lunkenheimer Co.
High pressure globe valves.....
.....Reading Steel Casting Co.
High pressure fittings.....
.....Reading Steel Casting Co.
Piping fabricated and installed by.....
.....Benj. F. Shaw Co.
Small high pressure valves.....
.....Manning, Maxwell & Moore, Inc.
High pressure steam traps.....
.....W. H. Nicholson & Co.
Non-return valves for boilers.....
Elliott Co. and Foster Engineering Co.

Instruments

Condensate meters.....
The Bailey Meter Co. and Simplex Meter Co.
Steam Flow meters..The Bailey Meter Co.
Boiler meters.....The Bailey Meter Co.
Recording thermometers and gages.....
.....The Foxboro Co.
Indicating thermometers.....
.....Precision Instrument Co.
Test wells.....Rieker Instrument Co.

Main Electrical Equipment

3 Westinghouse E. & M. Co. 11,765 kv.a. single phase, oil insulated, self cooled transformers, 60 cycles, 13,200 to 33,000 and 66,000/114,000Y v.
3 General Electric Co. 4167 kv.a. single phase, oil insulated self cooled transformers, 60 cycles, 2300 to 33,000 and 66,000/114,000Y v.
1 General Electric Co. Type FKO-136-3258-A-F2—800 amp., 110,000-v. electrically operated oil circuit breaker.
3 General Electric Co. Type KC-235 current transformers, 115,000 v.. 60 cycles.
1 General Electric Co. potential transformer, 110,000 to 110 v.
1 Westinghouse E. & M. Co. type O-221 oil circuit breaker, 3 pole single throw, 2000 amp., 15,000 v., electrically operated.
36 General Electric Co. Type FKR-132B-TPST-15,000 v., electrically operated oil circuit breakers for 2300 v. station auxiliaries.
Outdoor steel structure for transformer buses and 110,000-v. substation. Steel fabricated by Lehigh Structural Steel Company.
2 Hi Voltage, 132,000-v. air break switches, 3-pole, gang operated.
1 Hi Voltage, 132,000-v. balanced type disconnecting switch, 3-pole, gang operated.
1 Hi Voltage, 15,000 v.. 4000 amp., gang operated disconnecting switch.
1 Hi Voltage, 15,000 v., 2400 amp., gang operated disconnecting switch.
2 Hi Voltage 35,000 v., 3-pole, gang operated air break switches.

Switchboards

1 Generator field and exciter switchboard.
2 House service switchboards for control of 2300-v. station auxiliaries.
2 Boiler control switchboards.
1 House service switchboard for control of 220-v. station auxiliaries and lighting. Built by Pringle Electric & Mfg. Co.
2 2300-v. cell structures complete with oil circuit breakers, disconnecting switches, main and auxiliary buses with connections and instrument transformers.

immediately adjacent to the turbine room, and is accessible from the latter. There are trash racks not only at the point of intake to the water tunnel at the river, but also at the screen house in front of the revolving screens. This triple screening arrangement was deemed necessary due to the fact that the Johnson City sewer line is located just above the intake along the shore line and as a consequence difficulty has been encountered in keeping the condensing water clean.

Feedwater Heating and Heat Balance Control

Feedwater is heated by two stages of bleeder heating with an evaporator and evaporator condenser in parallel with the second stage. The condensate from the bleeder heaters is pumped back into the condensate line. A simple diagram of the unit No. 6 system is shown in Fig. 4, while in Fig. 7 is shown the complete flow and heat balance diagram of the 1927 extension.

Referring to Fig. 4, which shows conditions for a load of 26,000 kw., condensate removed from the condenser at about 86 deg. F. is first pumped to the steam jet air pump, where its temperature is raised to about 90 deg. F.; is then sent to the first bleeder heater. This heater takes steam from the turbine at 4.89 lb. abs. pressure, adds about 65 deg. to the temperature of the condensate, and brings it up to 155 deg. It (the condensate) next passes to the evaporator condenser, where an additional gain of 32.5 deg. is realized, and at a temperature of 187.5 deg. it goes into the second bleeder heater, where the condensate temperature is brought up to 210 deg. F. This last heater is operated at 19.4 lb. abs. The water next flows to the deaerating jet heater (not shown on Fig. 4), which is operated at approximately atmospheric pressure and which overflows into the storage tank in the basement (Fig. 7). Water is recirculated from the storage tank to the heater tank to maintain the temperature in the storage tank. The boiler feed pumps take the water direct from the heater tank.

Ross feedwater heaters are used in this system, one designed to heat 261,850 lb. of water from 47 deg. to 158 deg. F. and the other, 297,000 lb. from 159 to 213 deg. F. In construction, the two are practically identical, each having 1130 sq. ft. of 5/8-in. O. D. Muntz metal tubes.

Makeup is supplied by a Griscom-Russell, horizontal, bent tube evaporator of the scale-shedding, submerged type with a four-pass horizontal evaporator condenser. The capacity of the apparatus is 7600 lb. of distilled water per hour at 26,000-kw. load on the turbine. The deaerating heater is a Cochrane unit of the cylindrical tray type having a jet heater head. It has a capacity of 400,000 lb. of feedwater per hour.

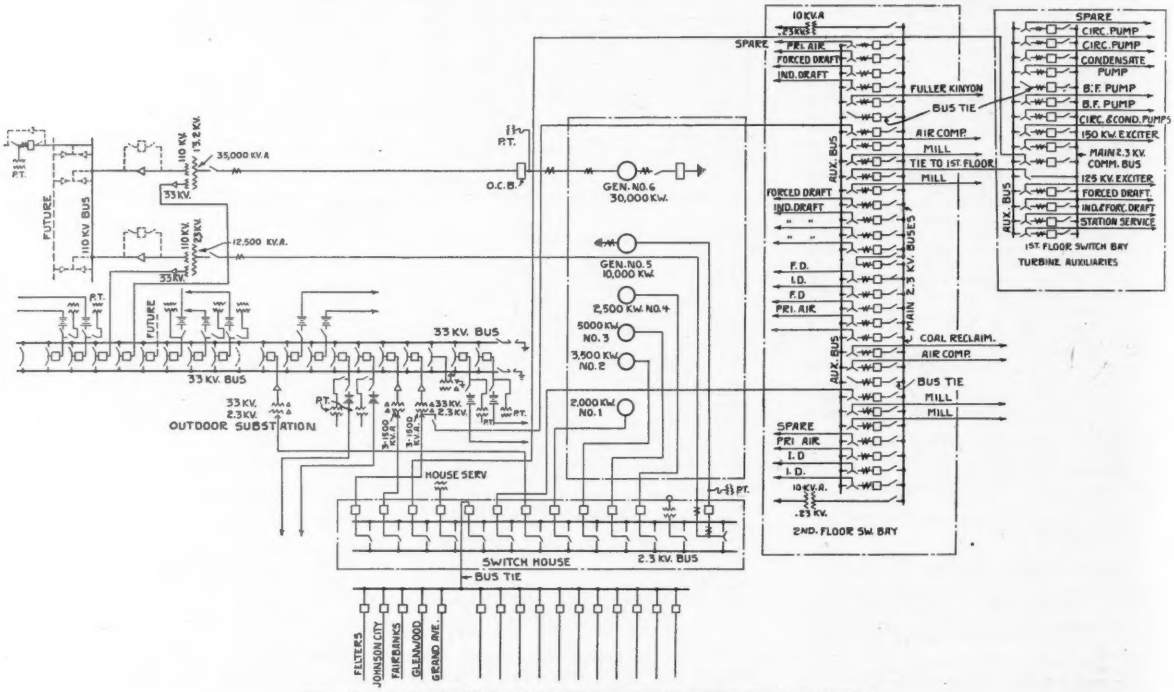


FIG. 8. SINGLE LINE DIAGRAM OF ELECTRICAL SYSTEM

Electrical Features

With the installation of the new 30,000-kw. generator the electrical system was enlarged and altered to permit the 13,800-v. unit to be connected to the existing system. As is indicated in the single line diagram of the electrical system, the first five generating units were all 2300-v. machines and were connected directly through circuit breakers to duplicate 2300-v. buses. These buses were tied in with 33,000-v. buses through several banks of 33,000/2300-v. transformers. Feeders leaving the station were taken off both the 2300 and 33,000-v. buses.

The 13,200-v. machine, it will be noted, feeds directly into a bank of three Westinghouse 13,200/33,000 and 66,000/114,000-Y volt transformers, which in turn connect to the 110-kv. bus. The 33,000-v. windings of these transformers are connected to the existing 33,000-v. buses. Another bank of transformers (2300/33,000 and

66,000/114,000 Y volts) is connected between the 110-kv. bus and the existing 2300-v. bus with the 33,000-v. winding connected to the 33,000-v. bus.

The new generator is a 35,000-kv.a., Westinghouse, 13,800-v., 3-phase, 60-cycle, 1800-r.p.m. machine, with a 120-kw., 250-v., direct connected exciter. The capacity is 30,000 kw. at 85 per cent power factor. This generator was the first machine using the skeletonized frame and sheet steel construction developed by the Westinghouse Electric & Mfg. Co. The stator frame is split in two sections at right angles to the axis of the rotor. Each half is a complete annular casting bolted to the other to form the frame. The complete frame is skeletonized as much as permissible, so that it acts as a guide and support for the stator laminations only. The entire stator was wound at the factory and shipped complete on a special type of low center railway car.

The new unit has been operating since November, 1926, with entirely satisfactory results.

In conclusion, we acknowledge our indebtedness to J. A. Powell and Wm. P. Saunier, engineers with W. S. Barstow & Co., for assistance in supplying us with data and illustration material forming the basis of this article.

Economies of Combining Industrial Power Plants

ADVANTAGES TO BE GAINED BY PROVIDING A CENTRAL POWER AND HEATING PLANT FOR SEVERAL ADJACENT INDUSTRIES ARE WORTH CONSIDERING. BY WM. W. GAYLORD

CONSIDERABLE PUBLICITY has been given the savings to be made by public utilities that supply adjacent sections by combining the power generation in one large, centrally located, generating station, but little, if anything, has been said of the possibilities as applied to industrial power plants.

Now that the cost of power and heat is becoming an increasingly important factor in many industries it appears that the advantages to be gained and the difficulties involved in providing a central power and heating plant for several adjacent industrial plants are well worth considering. To show the full advantages, as well as all the difficulties, this investigation must consider the steam for heating and process work as well as the electric power.

Often a little study of a group of industrial plants will show a diversity of power and heat demands that by a simple system of inter-connection could be balanced with considerable advantage to each individual plant. Of course it will often be found that the plants are competitors, or engaged in different lines of business having few, if any, common interests, but neither condition should prevent the establishing of a common source of supply for steam and electrical energy at a material saving to all. In many cases, the franchise of the public utility company will also have to be considered, but an arrangement of joint ownership will usually eliminate this difficulty. In case joint ownership is decided upon, the system of accounting and charges to each plant must be carefully worked out and proper recording instruments installed to obtain the necessary records.

As an example of the possible gains of such a system, consider four plants A, B, C and D grouped on the bank of a small stream and having the following steam and power requirements at present being supplied by miscellaneous equipment.

FOUR REPRESENTATIVE PLANTS FORM BASIS OF COMPARISON

A. A light textile plant doing some dyeing and mercerizing. The power load averages 100 kw. with a connected lighting load of 35 kw. The maximum demand for process steam is 2000 lb. per hr. and is practically steady during working hours. The demand for heating steam runs up to 3000 lb. per hr. Present equipment consists of two 100-hp. h.r.t. boilers operating at 200 lb. gage and a 150-kw. generator direct connected to a non-condensing uniflow engine having a water rate of 37 lb. per kw-hr., supplying process and heating steam at 10 lb. gage. This equipment is about 12 yr. old. All power required is generated and the excess exhaust steam is wasted.

B. A machine tool manufacturer. The power load averages 200 kw. with a connected lighting load of 50 kw. There is a constant demand of 500 lb. per hr. for process steam during working hours and a maximum demand of 15,000 lb. per hr. for heating steam. The present equipment consists of a 25-hp. low pressure boiler for use in the non-heating season and three 167-hp. horizontal return tubular boilers designed for 150 lb. gage working pressure but now being operated at 20 lb. gage. Space was provided in the power house for the installation of an engine and generator but these have not been installed as the plant is buying power from the local public utility. Boilers have been in use 5 yr. and are in good condition.

C. A textile plant using a large amount of process steam. The power load averages 150 kw. and is nearly constant, with a lighting load of 40 kw. Process steam demand, averaging 10,000 lb. per hr., is practically constant during working hours. There is also a maximum heating load of 8000 lb. of steam per hr. Present equipment consists of three 200-hp. underfeed stoker fired water tube boilers, designed to operate at 200 lb. gage, 225 per cent rating, and a 200 kw. generator, designed to operate at 80 per cent power factor and capable of continuous operation at 25 per cent overload, direct connected to a non-condensing uniflow engine which has a water rate of 40 lb. per kw-hr. Both process and heating steam are supplied at 15 lb. gage. This equipment has been in use 6 yr. but is in first class condition. There is room for the installation of another unit in the generator room and space to extend the boiler room.

D. A metal working plant using no process steam and only a small amount for heating. The power load averages 500 kw. with a connected lighting load of 60 kw. Most of the plant is heated by the metal working furnaces so that the maximum demand for heating

steam, supplied by low pressure fire-box type steel heating boilers, is 4000 lb. per hr. Power is purchased from the local public utility.

Two Possible Methods Must Be Considered

All four plants are operated 10 hr. a day 300 days a year. A careful consideration of the power and steam requirements of these plants and of the equipment installed shows that there are two ways in which substantial savings can be made.

Scheme 1: The following changes in equipment and operation could be made in the various plants:

A. No changes, as it has a reasonably well balanced power and steam load.

B. Install a 225-kw. generator driven by a direct connected uniflow engine designed to be run non-condensing in the heating season when low pressure steam is required and condensing in the non-heating season. Plant B will then generate all its own power both summer and winter. Of course, when some heat is required, but not enough to use the total exhaust from the engine the excess exhaust steam must be wasted or else the steam for heating supplied direct from the boilers and the engine run condensing.

C. Install a 500-kw. extraction type turbo-generator and the necessary condenser. This unit would be arranged to run in parallel with the present engine driven generator. With this equipment plant C can supply all power and heating steam required by plant D with a relatively small increase in coal consumption and labor, and therefore at a much lower rate than plant D is at present paying.

Scheme 2: Consolidate boiler and power houses to supply all steam and power required by the four plants. This could be done by forming ABCD Co., owned jointly by the four plants, which would take over the power house of plant C at its appraised value and add such equipment as necessary to supply the required steam and power. Plants A, B and D would either keep their present equipment for emergencies or dispose of it. This method would require working out of an equitable method of apportioning operating costs of the combined power plant between the four plants which could probably best be done by metering the low pressure steam and electric power supplied to each and charging them at cost as calculated from the total operating cost of the power plant.

Determination of the cost of 1000 lb. of low pressure steam is relatively easy, but a fair determination of the cost of electric power per kilowatt-hour involves the question of whether a corresponding amount of low pressure steam was used, making the power largely a by-product. Thus the plant using low pressure steam during the hours that it uses power should be charged only the by-product cost for that portion of its power which corresponds to the steam used but must be charged the full cost for the remaining portion of its power while the plant using no low pressure steam must be charged the full cost for all power. As this method of operation will require the installation of steam mains and power lines from plants A, B and D to the combined power plant the investment charges on these must be added to the amount paid for steam and power.

To show what savings may be made it is necessary to figure the present annual operating costs for steam and power, for each plant, under present conditions and under each of the proposed new methods. These work out as follows:

Present Conditions

Plant A

Winter working days, steam for heat and process, 24 hr.	61,500 lb.
Winter holiday, steam for heat, 24 hr.	30,000
Winter working day, steam for power	6,550
Summer working day, steam for power, 24 hr.	16,450
Summer working day, steam for process	20,000
Then the total steam per year will be	
6,550 × 160 days, winter power	1,048,000
61,500 × 160 days, winter heat and process	9,840,000
30,000 × 25 days, winter heat holidays	750,000
(16,450 + 20,000) × 140 days, summer power and process	5,103,000
	16,741,000
Assuming an average evaporation of 7.6 lb. of water per lb. of coal this will require per yr	1,100 t.
Allow for banking, t. per yr	75
Total coal per yr.	1,175
Yearly operating costs will be:	
Coal, 1175 tons at $7.00	$8,225.00
Supplies, misc.	400.00
Labor, 3 men	7,500.00
Fixed charges 18 per cent on present plant value of $15,000	2,700.00
Repair to plant	500.00
Total	$19,325.00

Plant B

Winter working day steam for heat and process, 24 hr.	210,500 lb.
Winter holiday steam for heat	144,000
Summer working day steam for process	5,000
The total steam per year should be based on a 15 day longer heating season as so little process steam is used that buildings will require heat for a longer period.	
210,500 × 175 working days, winter	36,750,000 lb.
144,000 × 25 holidays and Sundays, winter	3,600,000
5,000 × 125 working days, summer	625,000
Total steam per yr.	40,975,000
Assuming an average evaporation of 7.6 lb. water per lb. of coal, will require, per yr	2,695.4 t.
Allow for banking, per yr	15
Total coal per year	2,710.4
The yearly use of current will be	
175 days at 2185 kw-hr	392,325 kw-hr.
125 days at 2000 kw-hr	250,000
Total	642,325
Then the yearly operating cost will be	
Coal 2,710.4 t. at $7.00	$18,972.80
Current 642,325 kw-hr. at $0.025	16,100.00
Supplies, misc.	500.00
Repairs	500.00
Labor, 1 man for all year, 2 for 7 months	5,650.00
Fixed costs, 15 per cent of present plant value of $20,000	3,000.00
Total	$44,722.00

Plant C

Winter working day total heat and process steam, 24 hr.	201,000 lb.
Winter holiday total heating steam, 24 hr.	72,000
Summer working day total process steam	109,000
Winter day, steam to power	6,240
Summer day, steam to power	6,000
Then total steam per yr. will be	
201,000 × 160 working days, heat and process	32,160,000 lb.
72,000 × 25 holidays, heat	1,800,00
109,000 × 140 working days, process	15,260,000
6,240 × 160 working days, power	998,400
6,000 × 140 working days, power	840,000
Total	50,998,400

Assuming an average evaporation of 8.4 lb. of water per lb. of coal this requires	3,035.6 t.
Allow for banking in summer, per yr	125
Total	3,160.6
Then the yearly operating cost will be	
Coal, 3,160.6 t. at $7.00	$22,124.20
Supplies, misc.	800.00
Labor, 4 men	10,000.00
Repairs to plant	600.00
Fixed charges 15 per cent on present plant value of $60,000	9,000.00
Total	$42,924.20

PLANT D

Steam used for heating only, maximum rate, 4000 lb. per hr.	
Average throughout heating season, 35 per cent of max., 200-day season	
4000 × 200 × 24 × 0.35, per yr	6,720,000 lb.
Assuming an average evaporation of 8 lb. of water, per lb. of coal requires, per yr	420 t.
The yearly use of current is	
175 days at 5200 kw-hr	910,000 kw-hr.
125 days at 5000 kw-hr	625,000
Total	1,535,000
Then the yearly operating cost will be	
Coal, 420 t. at $7.00	$ 2,940.00
Current, 1,535,000 kw-hr. at $0.024	36,840.00
Labor, 1 man, 7 months; 2 men, 4 months	2,200.00
Fixed charges, 15 per cent on present plant value of $6,000	900.00
Total	$42,880.00

Under Scheme 1 the cost of operation of plant A remains the same but the cost of operation of plant B changes. Assume the installation of a 225-kw. generator driven by a uniflow engine arranged to run non-condensing in the heating season and condensing in the non-heating season. This engine will have a water rate of 21 lb. per kw-hr. when running condensing and 38 lb. per kw-hr. when running non-condensing against 5 lb. back pressure.

Installed, ready to run, including jet type engine condenser, steam and water piping, switchboard, etc., the cost of this generator will be about $90 per kw. or $20,250. The steam required for power in addition to that which would be required for heating may be estimated by assuming that 80 per cent of the exhaust steam can be used for heating and that 90 per cent of the steam supplied can be recovered in the exhaust for heating. The steam charged to power is,

In winter	
—392,325 × 0.1 × 38	1,490,835 lb.
—392,325 × 0.2 × 0.9 × 38	2,683,503
In summer	
250,000 × 21 (condensing)	5,250,000
	9,424,338
At an evaporation of 7.6 lb. of water per lb. of coal this requires, per year	620 t.
Allowing for banking	60
For heating and process	2,710.4
Total for yr	3,339.4
Then the yearly cost will be	
Coal, 3,339.4 t. at $7.00	$23,732.80
Supplies, misc.	700.00
Repairs	600.00
Labor	10,000.00
Fixed costs, 15 per cent on $20,000 + $20,250	6,037.50
Total	$41,070.30

Cost of operating plant C to supply all power and steam to plants C and D can be calculated on the following basis:

Winter working day total steam for power, heat and process	307,200 lb.
Winter holiday total steam for heat	105,600
Summer working day total steam for power and process	194,000
Then the total steam per year will be	
307,200 × 160 working days, heat, power and process	49,152,000 lb.
105,600 × 25 holidays, heat	2,640,000
194,000 × 140 working days, power and process	27,160,000
Total steam per yr	78,952,000
Assuming an average evaporation of 8.4 lb. of water per lb. of coal requires	4,699.5 t.
Allowing 150 t. for banking	150
Total coal per yr	4,849.5
Then the yearly operating cost will be	
Coal, 4,849.5 t. at $7.00	$33,946.50
Supplies, misc.	1,200.00
Labor, 5 men	13,000.00
Repairs	1,200.00
Fixed charges 15 per cent on $95,000. Original plant $60,000.00 and new 500-kw. generator at $70.00 per kw. = $35,000	13,750.00
Total	$63,096.50

As plant C is now selling both steam and current it becomes necessary to apportion the cost between them. First we must determine the cost of 1000 lb. of steam from the above costs, as follows:

Coal	$33,946.50
Supplies	600.00
Labor	10,500.00
Repairs	900.00
Fixed charges	5,000.00
Total	$50,946.50

Then of the total amount of steam generated 23,000,000 are chargeable to power which at $0.656 per 1000 lb. will be the steam cost of power. Then the total power cost will be

Steam, 23,000 at $0.656	$15,088.00
Supplies	600.00
Labor	2,500.00
Repairs	300.00
Fixed charges	9,250.00
Total	$27,738.00

Then if plant C uses 459,600 kw-hr. per yr. and plant D uses 1,535,000 kw-hr. per yr., the unit cost is $0.0139 per kw-hr. Now if steam is sold to plant D at $0.66 per 1000 lb. and electricity at $0.0150 the return will be,

6,720,000 lb. steam at $0.66	$ 4,435.20
1,535,000 kw-hr. at $0.0150	23,025.00
Total	$27,460.20

Leaving the net cost of power and steam to plant C $35,636.30, or $6,887.70 less than when no power and steam are sold, this gives a return of 19¾ per cent on $35,000 additional investment in addition to the 6 per cent already figured. Cost of plant D, buying both power and steam, will be what it must pay for the power and steam, the fixed charges on its abandoned boiler plant, and the added investment to bring steam and electricity from the power house of plant C. Assuming the plants are adjacent, this investment probably would not be over $3000. Then the costs to plant D will be:

Steam, 6,720,000 at $0.66 per 1000 lb.	$ 4,435.20
Electricity, 1,535,000 kw-hr. at $0.015	23,025.00
Fixed charge on abandoned boiler plant	900.00
Fixed charge, connection to plant C	450.00
Total	$28,810.20

This is a substantial saving over generating their own steam and buying power, as only $3000 had to be invested to make the change.

Consolidated Power House of ABCD Co. Under Scheme 2

Power plant C is taken over by ABCD Co. at a value of $60,000 and an addition put on containing two new 300 hp. boilers stokered to run normally at 200 per cent rating and 250 per cent for 3 hr. and a new 1000 kw. extraction turbine with condenser and auxiliaries. A new switchboard and out-going feeders to plants A, B and D and a low pressure piping system for distributing steam at 15 lb. pressure to these plants must also be installed.

The cost will run as follows:

Boilers, stokers, chimneys, etc.	$ 60,000
Turbine, condenser, etc.	40,000
Piping	12,000
Switchboard and wiring	7,000
Building	30,000
Total	$149,000
Winter working day, total steam	529,000 lb.
Winter holiday, total steam	275,000
Summer working day, total steam	261,250
Then the total steam per year will be	
529,000 × 165 working days, winter	87,285,000 lb.
275,000 × 25 holidays, winter	6,875,000
261,250 × 135 working days, summer	35,268,750
Total, per yr.	129,428,750
Assuming as before an evaporation of 8.4 lb. water per lb. coal the yearly coal required will be	7,704.69 t.
Additional coal allowed for banking	200
The total coal used per year is	7,904.69
And the yearly cost will be	
Coal, 7,904.69 t. at $7.00	$ 55,332.83
Supplies, misc.	1,600.00
Labor, 6 men	15,500.00
Repairs	1,500.00
Fixed charges 15 per cent on $209,000.00	31,350.00
Total	$105,282.83

As this plant supplies both steam and electric current, it will be necessary to apportion the cost between them. To do this it is first necessary to find the cost of steam per 1000 as before.

Coal	$55,332.83
Supplies	800.00
Labor	12,000.00
Repairs	1,200.00
Fixed charges	15,000.00
Total	$84,332.83

TABLE I. STEAM AND POWER ANALYSIS SHOWING POUNDS OF STEAM PER YEAR CHARGEABLE TO HEAT, PROCESS AND POWER IN EACH PLANT

		Winter		Summer	
		Process and Heat	Power	Process	Power
Present Equipment	Plant A	10,590,000	1,048,000	2,800,000	2,303,000
	Plant B	40,350,000	0	625,000	0
	Plant C	33,960,000	998,400	15,260,000	840,000
	Plant D	6,720,000	0	0	0
Scheme No. 1	Plant A	10,590,000	1,048,000	2,800,000	2,303,000
	Plant B	40,350,000	1,490,835	625,000	5,250,000
	Plant C	33,960,000	9,800,000	15,260,000	11,900,000
	Plant D	6,720,000		0	
	Total	91,620,000	12,338,835	18,685,000	19,453,000
Scheme No. 2	Plant A	10,590,000		2,800,000	
	Plant B	41,350,000	2,460,000	625,000	16,583,750
	Plant C	33,960,000		15,260,000	
	Plant D	6,720,000		0	
	Total	91,620,000	2,460,000	18,685,000	16,583,750
		18,685,000			2,460,000
		110,305,000	Totals for whole year		19,043,750

The cost per 1000 lb. of steam generated will then be $84,332.83 ÷ 129,428.75 or $0.6533.

Low-Pressure Steam Sold on a Heat-Content Basis

Steam and power analysis, Table I, show that 110,305,000 lb. of steam at 15 lb. gage pressure are required by the four plants for heating and process work. The heat content of saturated steam at 15 lb. gage pressure is 97 per cent of that at 200 lb. gage pressure, so this may be charged at 97 per cent of the cost of the high pressure steam as determined above or, $0.6533 × 0.97 per 1000 lb. Then the cost of steam chargeable to power will be $84,332.83 — 110,305 × $0.6317 = $84,332.83 — $69,679.67 = $14,653.16. Table II also shows that 2,953,575 kw-hr. per year are required.

Cost of the current can be divided into two parts, first the steam cost and second the cost representing labor, supplies, repairs and fixed charges. The first will vary with the low pressure steam demand and to apportion it fairly between the plants it must be divided so that those using large quantities of low pressure steam are given proper credit. To do this, it has been assumed that for that portion of the power corresponding to the low pressure steam used by each plant only 13 per cent of the cost of the steam required by the generating unit is chargeable to power, as the other 87 per cent is recovered in the low pressure steam. Thus if the water rate of the turbine at maximum extraction is 36 lb. per kw-hr. the steam cost per kilowatt will be 36 × 0.13 × 0.0006317 = $0.003 per kw-hr.

Analysis of the power demands of the four plants, Table II, shows that 1,178,575 kw-hr. are chargeable at $0.003 per kw-hr. for steam or $3,535.73 while the remaining 1,775,000 must bear the balance of the steam cost or $14,653.16 — $3,535.73 = $11,117.43 which is equal to $0.00626 per kw-hr.

The second part of the cost will be the same for all current generated, and may be found from the total labor, supplies, and fixed charges chargeable to power. Total yearly costs are:

Labor	$ 3,500.00
Supplies	800.00
Repairs	300.00
Fixed charges, 15 per cent on $109,000	16,350.00
Total	$20,950.00

Costs per kw-hr. then become $20,950.00 ÷ 2,953,757 or $0.0071.

This will mean that the 1,178,575 kw-hr. for which there is a corresponding use of low-pressure steam should be charged at $0.0030 + $0.0071 = $0.0101 per kw-hr. while the remaining 1,775,000 kw-hr. should be

TABLE II. ANALYSIS OF POWER DEMANDS SHOWING DISTRIBUTION OF STEAM CHARGEABLE TO POWER UNDER SCHEME NO. 2

	Power equivalent to low pressure steam used, kw. hr.		Power in excess of low pressure steam used, kw. hr.		Total power used
	Winter	Summer	Winter	Summer	kw. hr.
Plant A	183,750	65,000	0	60,000	308,750
Plant B	392,325	0	0	250,000	642,325
Plant C	280,000	187,500	0	0	467,500
Plant D	70,000	0	840,000	625,000	1,535,000
Total	926,075	252,500	840,000	935,000	2,953,575
	1,178,575		1,775,000		

TABLE III. TABULATED COMPARISON OF YEARLY OPERATING COSTS

	Plant A.	Plant B.	Plant C.	Plant D.	Total All Plants
Present Equipment Scheme	$19,325.00	$44,722.80	$42,524.00	$42,880.00	$149,451.80
No. 1	19,325.00	41,070.30	35,636.30	28,810.20	124,841.80
Scheme No. 2	15,076.46	32,779.68	32,128.79	25,887.04	105,871.97
Yearly Savings Over Present Operation					
Scheme No. 1	$ 0.00	$ 3,652.50	$ 6,887.70	$14,069.80	$ 24,610.00
Scheme No. 2	4,248.54	11,943.12	10,395.21	16,992.96	43,579.83
Percentage Return on Additional Investment					
Scheme No. 1	0.0%	18.0%	19.6%	468.0%	42.2%
Scheme No. 2	14.7%	18.6%	19.6%	22.9%	19.5%

charged at $0.00626 + $0.0071 = $0.01336 per kw-hr. Yearly costs to the various plants then become:

Plant A

To use steam and current from the combined plant, A must install low-pressure piping and wiring to connect to its present distribution system. Assume that this will cost $4000. Then the yearly cost will be made up of the charges for low-pressure steam, current and fixed charges on its idle steam plant and cost of connection to combined plant.

Steam, 13,390,000 lb. at $0.632 per 1000 lbs	$ 8,462.48
Power, 248,750 kw-hr. at $0.0101	2,512.38
60,000 kw-hr. at $0.01336	801.60
Fixed charges, 15 per cent on $4000 + 18 per cent on $15,000	3,300.00
Total	$15,076.46

Plant B

Cost of piping and wiring to the combined power plant is $8000, which, added to the $20,000 value of the boiler plant, makes an investment of $28,000 on which fixed charges must be figured. Then the yearly cost will be:

Steam, 33,350,000 lb. at $0.632 per 1000 lb	$21,077.20
Power, 392,325 kw-hr. at $0.0101	3,962.48
250,000 kw-hr. at $0.01336	3,540.00
Fixed charges, 15 per cent on $28,000	4,200.00
Total	$32,779.68

Plant C

This plant does not have to make any new connections from the power plant to its distribution system and can also credit the interest on the sale price of its power plant against the cost of steam and power.

Steam, 49,220,000 lb. at $0.632 per 1000 lb	$31,007.04
Power, 467,500 kw-hr. at $0.0101	4,721.75
Total	$35,728.79
Credit, 6 per cent on $60,000	3,600.00
Net cost of steam and power	$32,128.79

Plant D

Cost of piping and wiring to combined power plant is $3000. Then yearly total is:

Steam, 6,720,000 lb. at $0.632 per 1000 lb	$ 4,247.04
Power, 66,750 kw-hr. at $0.0101	674.18
1,468,250 kw-hr. at $0.013364	19,615.82
Fixed charges, 15 per cent on $9,000	1,350.00
Total	$225,887.04

TABLE IV. ADDITIONAL INVESTMENTS NECESSARY AT THE DIFFERENT PLANTS UNDER SCHEME NO. 1 AND SCHEME NO. 2

	Scheme No. 1	Scheme No. 2			
		Steam Capacity	Power Capacity	Piping & Wiring	Total for Plant
Plant A	$ 0.00	$ 8,400.00	$16,400.00	$ 4,000.00	$ 28,800.00
Plant B	20,250.00	25,820.00	30,400.00	8,000.00	64,220.00
Plant C	35,000.00	30,100.00	23,100.00	0.00	53,200.00
Plant D	3,000.00	6,680.00	68,100.00	3,000.00	77,780.00
Totals	$58,250.00	$71,000.00	$138,000.00	$15,000.00	$224,000.00

Table III shows the relative yearly operating costs of the four plants under the present method as well as each of the proposed methods. It is evident that the second proposed method makes much the greater savings in steam and power cost but requires the larger investment, so that return on the relative investments must also be considered.

To do this, it will be necessary to apportion the total investment in the combined plants among the four joint owners. Obviously this cannot be done either on a connected load or boiler horsepower required basis alone, but must be based on a combination of the two. An inspection of the steam and power analysis tables shows that 85 per cent of the total steam generated would be required if no power were generated, therefore 85 per cent of the installation cost of the boilers should be apportioned in proportion to the maximum steam demands of the plants. Assume that 1200 hp. of boilers can be installed at $70 per hp. or $84,000. Then 85 per cent of this is approximately $71,000 which will be apportioned as shown in Table IV. The balance of the total station cost of $138,000, or $115 per kw. installed capacity, will be divided proportionally to the connected loads as shown in table.

Tabulations of yearly savings and percent return on additional investments, Table III, show a greater percentage return by scheme 1 but a greater total saving by proposed method 2 although this also gives a satisfactory percentage return on the investment. Method 2 is the one, therefore, that would be recommended. While each group of plants must be studied as a separate problem, the example given clearly indicates the savings that might be made by combined power plants for adjacent industrial plants.

In water supply paper 579 of the Geological Survey recently published by the Department of the Interior is given information about the capacity of different types of prime movers installed in the industries of the United States from 1849 to 1923. It gives monthly figures of production of electricity and consumption of fuel by public utility power plants from 1919 to 1926 and estimates of potential water power resources of the country, as well as reports of developed water power during the different years.

While some of the data have been previously published, the statistics are now brought together in such form as to be available for study and to serve as a basis for any future study of the problems of power utilization in relation to economics and Government.

Copies may be had from the Geological Survey, Washington, D. C.

Excellence is never granted to man but as the reward of labor.—Sir Joshua Reynolds.

Air Preheater Fills Several Power Plant Needs

When Properly Applied to Each Individual Set of Conditions, Air Preheater Acts to Reduce Stack Losses, Improve Combustion, Permit Stage Feedwater Heating, Sometimes in Conjunction with an Economizer and Justifies Itself from Economic Standpoint

HEAT LOST up the chimney of a power plant has always been a large source of wasted energy. With increasing steam temperatures and pressures, the temperature of the gases leaving the last row of boiler tubes has increased; higher ratings also have tended to increase the differential between tube temperatures and leaving gas temperatures and this has had the effect of increasing the heat losses up the stack.

Any means of recovering this heat in the form of usable energy has been attractive to the engineer, hence the larger number of economizer installations in this country and abroad, in which the feedwater before entering the boiler is made to absorb a portion of this heat. In many large central stations, however, the feedwater is now efficiently heated by steam bled from the

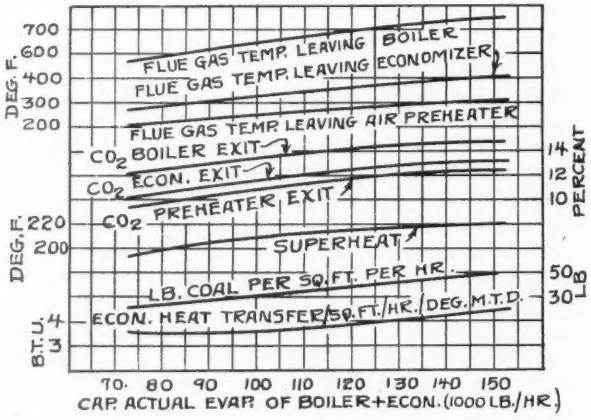


FIG. 1. TEST PERFORMANCE, BOILER NO. 2, UNIT NO. 1, CRAWFORD AVE. STATION

turbines. In such cases, air preheaters are often used to permit the recovery of heat which would otherwise be wasted in the flue gas.

Even with economizers installed, there is opportunity to recover additional waste heat by means of an air heater, as a result of the high ratings and consequent high boiler outlet gas temperatures which are becoming the rule in modern practice. When an integral economizer is installed in the last pass of the boiler, the outlet gas temperatures are frequently high enough to justify investment in an air preheater. A number of installations have also recently been designed with independent economizers and air heaters. Figure 1 shows typical conditions in such an installation.

Beneficial Effects of the Air Heater

Beneficial effect of the air heater extends considerably beyond merely recovering a certain number of heat units from the stack and reintroducing them into the stream of gas crossing the boiler tubes. It has been found that preheated air improves combustion, reducing the time required for any particle of fuel to disintegrate and burn completely. Combustible in the ash is thus reduced and more fuel can be burned per square foot of grate area for the same furnace volume. Figure 2 shows results of tests on three boilers, demonstrating how combustible in the ash was reduced with increase in preheated air temperature.

Consideration must be given, of course, to the ability of the furnace itself to stand up under the increased heat liberation made possible by use of preheated air. This contingency has made necessary the development

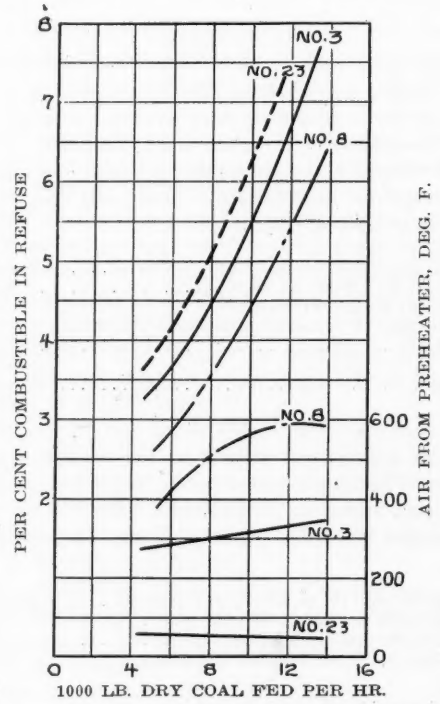


FIG. 2. INCREASE OF PREHEATED AIR TEMPERATURE ON TESTS OF THREE BOILERS REDUCES COMBUSTIBLE IN ASH. BOILERS AND STOKERS SAME SIZE

Boiler No. 3—Economizer and small tubular air preheater.
Boiler No. 8—Large Tubular Preheater only.
Boiler No. 23—Economizer only. Air temperature is that of room; it decreased slightly during test.

of improved types of refractory material and, at the same time, has brought about the use of the water-cooled wall. Thus, with proper design to fit the given conditions, full use can be made of the benefits of preheated air to improve combustion.

An air heater has an advantage of great importance as a heat recovery medium and that is that the temperature differences are greater than in the case of the economizer. This important theoretical consideration, however, is subject to many practical qualifications, among which is the difficulty of carrying large air ducts from the air heater back through the plant to the furnace without great heat losses due to radiation and leakage. Ducts for such purposes are sometimes made of insufficiently heavy material so that they may not

have long life. Insulation of high temperature air ducts is expensive.

Despite the undoubted theoretical advantages resulting from the use of preheated air, careful analysis must be made, in any power plant design, of the entire plant before it can be definitely stated whether or not air preheaters should be used. Their performance is

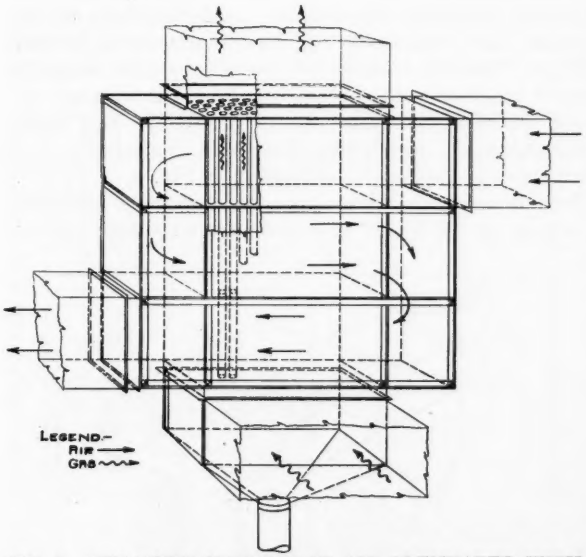


FIG. 3. ONE FORM OF TUBULAR AIR PREHEATER WITH TUBES ARRANGED VERTICALLY

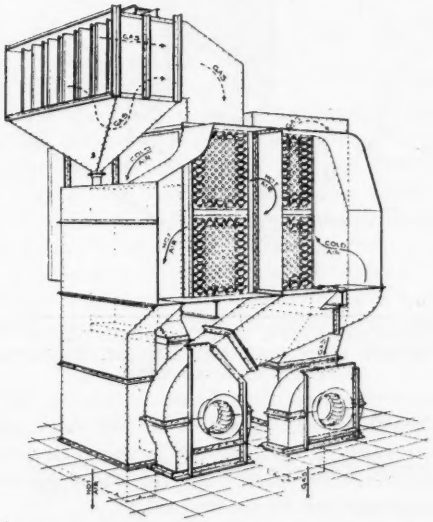


FIG. 4. ONE FORM OF TUBULAR AIR PREHEATER WITH TUBES ARRANGED HORIZONTALLY

closely interwoven with the operation of the entire plant. They are not only a part of the equipment used in burning the fuel but also form a factor to be considered in determining the amount of stage bleeding of the main units. In short, they must be selected, like all other equipment, on a basis of final dollar economy. The really important result to be obtained is low cost of steam or electric power and this does not always accompany the highest efficiency.

There are three general classes of air preheaters: tubular, plate and regenerative.

The tubular type consists of a group of tubes supported at each end in tube sheets. In the usual arrangement gas flows through the tubes and air outside and the transfer of heat occurs through the tube walls. The tubes may be either vertical or horizontal. They are sometimes rolled into holes in the tube sheets like boiler tubes or a packed glandular joint is used to make a tight connection to cast-iron tube sheets. In this case the tubes are easily replaceable without the special equipment necessary for cutting out and rolling in tubes and the gland permits the tubes to expand as necessary. It is claimed for the rolled-in joint that it can readily be kept tight and that the flexibility of the steel plate tube sheet is sufficient to take care of all necessary expansion.

Plate type heaters contain a series of steel plates separated by spacers. Gas and air flow in alternate narrow openings between the plates and the transfer of heat occurs through the plate. Guide strips are often used in both the gas and air passages to direct the flow

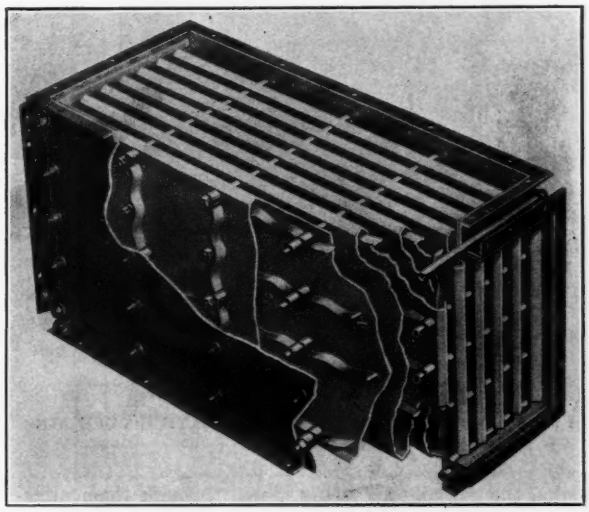


FIG. 5. ONE FORM OF PLATE TYPE HEATER, BUILT SO IT CAN BE ASSEMBLED IN VARIOUS COMBINATIONS OF SECTIONS

of gas and air and to prevent stratification and eddying. In the sectional form of plate air heater, Fig. 5, plates are assembled in sections of standard size at manufacturing plants and shipped to the point of installation in units all ready to assemble in place.

Air heaters may fail through corrosion at the cold end. This is the result of temperatures falling below the dew point and causing moisture to collect on the heating surface. The presence of sulphur in the gases will then form a weak sulphuric acid which, combined with the natural oxidation, due to the presence of water, will eventually corrode the tubes or sheets. In the case of plate type air heaters, designs are often used which provide for removing and reversing plates so that the cold end can be placed at the hot end and vice versa, after a reasonable amount of corrosion has taken place. When both ends have become corroded, the whole air heater surface has to be scrapped.

The regenerative preheater has elements which are alternately heated by hot gases and cooled by incoming cool air, so that a transfer of heat is effected from gas

to air. In the most familiar form of this apparatus, Fig. 6, a rotor having its axis vertical is built up out of a large number of plates alternately corrugated and flat, so that a large amount of heating surface is contained in a comparatively small space. The slow rotation of these elements carries them continuously from a stream of hot gas to a stream of cool air and back into the hot gas again. A cylindrical casing enclosing the rotor is divided into gas and air compartments which connect with the rotor by means of sliding sealed joints. Forced and induced draft fans, in one make of these units, are incorporated in the unit and are driven by the same motor that drives the rotating element. Another form of regenerative heater has stationary ele-

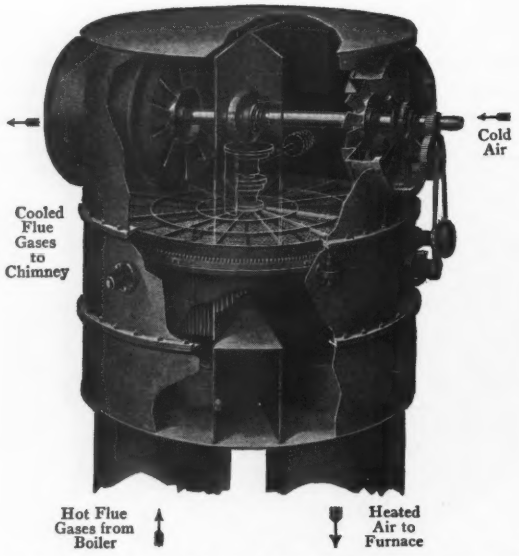


FIG. 6. ROTARY ELEMENT REGENERATIVE TYPE AIR PREHEATER

ments, the gas and air being blown through them alternately by means of a system of automatic valves, Fig. 7.

Detailed discussion of corrosion and methods of cleaning air preheaters is beyond the scope of this article.

Steam Air Preheaters

Preheaters mentioned above are constructed primarily to act as heat traps for the heat in the flue gas. To fit certain heat balance conditions that have arisen, air has in some cases been preheated by steam in specially designed heaters. In a few cases, this steam has been extracted from the main turbine, in others taken direct from the main steam line. One large station is at present using live steam to heat air for introduction into its coal pulverizing mills; although the air in this case is used primarily for drying the coal, it has the additional advantage of being introduced into the furnace as primary air with the pulverized coal.

Air Preheater Must Prove Its Dollar Economy

When selecting a heater, the size which gives greatest net return in dollars should be chosen. In considering this problem, it is necessary to offset value of gross fuel saved by the value of fuel corresponding to increased fan power consumption. It is also necessary to allow for fixed charges on the investment. Where slight difference in capacity of the plant at peak loads is of importance, consideration should also be given to the decrease in peak capacity due to additional fan power consumption required for the air heater.

Annual and daily load factor also affect preheater selection. Generally speaking, it is considered that plants with low load factors cannot afford to spend as much on auxiliary heat recovery equipment such as air heaters and economizers, as the plant with high load factor. Careful analysis of the influence of capacity factor has been made by one engineer, the influence of heat absorbing surfaces of air preheaters and economizers on the production costs of a typical plant at two capacity factors being plotted in Fig. 8, A and B. These curves are taken from an extremely complete analysis for the design of a plant for an annual output

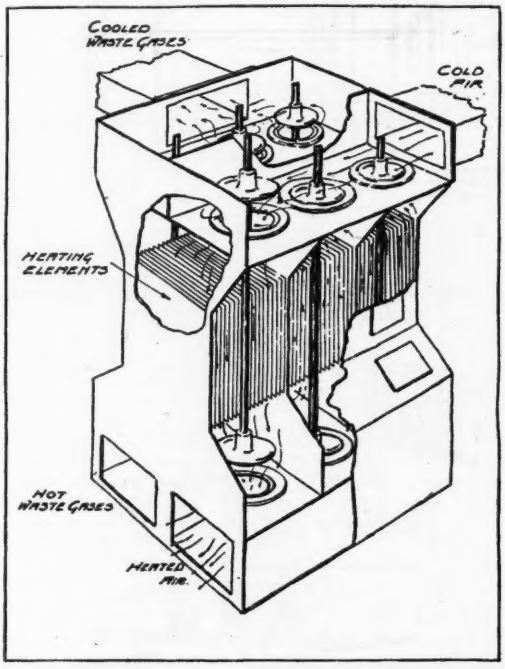


FIG. 7. REGENERATIVE AIR PREHEATER IN WHICH VALVES ADMIT FLUE GAS AND AIR ALTERNATELY TO HEATING ELEMENTS

of 125,000,000 kw-hr. at about 50 per cent capacity factor. As pointed out above, it is only after such an analysis of the whole plant that the dollar economy of the air preheater can be determined.

Typical Air Preheater Installations

It may be of interest to consider a number of actual installations.

At one large central station, rotary element type air heaters preheat the air to about 525 deg. F. This air is tempered to 380 deg. before delivery to the stoker, by being passed through an air-water economizer. Thus the air preheaters recover as much heat as possible from the flue gas; possibility of economizer corrosion is eliminated because the economizer handles only clean air and evaporated water; the temperature of the air to the chain grate stokers is kept low enough to prevent mechanical troubles.

In another plant used for district steam heating, economizers are placed directly above the boiler outlets, and above them are the air heaters of plate type construction, the gas passing through economizers and air heaters in series. The boilers are of large capacity, being capable of upwards of 320,000 lb. per hr. evaporation. They are of double-fired arrangement, having two gas outlets. In this case two economizers and two air heaters are installed per boiler. As this is a steam heating plant, no turbine bled steam is available and this is one reason for the use of both air heaters and

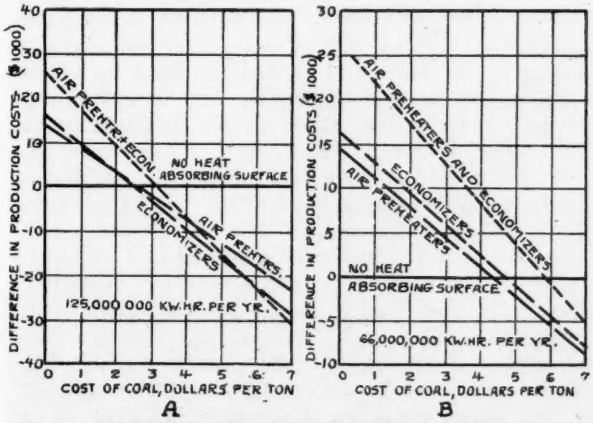


FIG. 8. ECONOMY OF HEAT-ABSORBING SURFACE IN FLUE GAS AT TWO CAPACITY FACTORS: A CORRESPONDS TO 50 PER CENT CAPACITY FACTOR AND B TO 25 PER CENT

economizers. Pulverized coal is burned and the secondary air temperature is carried up to a maximum of around 430 deg. The primary air to the burners is taken from the preheaters but tempered to about 160 deg. by admixture of boiler room air into the inlets of independent primary air fans.

At another large power station, an integral economizer is installed in the last pass of the boiler and a vertical tubular air heater takes the gases after they leave the economizer. In this case the surfaces in boiler, superheater, economizer and air heater are in the proportion of 5:1:2.5:7. When operating at approximately 350 per cent of rating, the gases are cooled to about 285

TABLE SHOWING VARIOUS PREHEATER CONDITIONS FOUND IN ACTUAL INSTALLATIONS

Type	Air heater Heating Surface	Developed Boiler Horsepower Each Heater	Gas Temperature In	Drop	Out	Air Temperature In	Rise	Out	Max. Draft Loss Gas Inches	Air Water
Horizontal Tubular	4032	3760	493	78	418	70	78	148	.35	.5
" " "	5000	1562	650	250	400	80	239	319	2.08	.85
" " "	14800	4500	485	195	290	75	186	261	0.95	0.90
Plate type	7550	4890	640	264	376	70	250	320	2.0	2.1
Vertical Tubular	18200	4200	675	304	371	80	291	371	0.65	0.80
" "	10100	6700	585	211	372	70	314	384	2.20	3.00
" "	19500	6700	950	300	650	80	350	430	2.7	0.8

deg. after passing through economizer and air heater and water is heated from 280 deg. to 350 deg. F., while air is heated to about 325 deg. F. before delivery to underfeed stokers. This is an example of the installation of both air heaters and economizers where stage bleeding from the turbines is also employed.

In a plant at which successive extensions have been made in the last four years, the design of each section is somewhat different. In the first section economizers only are used, with air-cooled furnace walls; in the next section economizers and horizontal tubular air heaters are installed; in the latest section economizers are omitted, vertical tubular air heaters only being installed. In each case stage bleeding from the turbine is used for heating the feedwater. The average air temperature to oil burners is 150 deg. for the first section, 300 deg. for the second section and 470 deg. in the last section. The changes made illustrate the constant and rapid development of contemporary power plant design.

Design figures are given in the accompanying table for a number of heaters which indicate the range of sizes, gas and air temperatures and draft and air

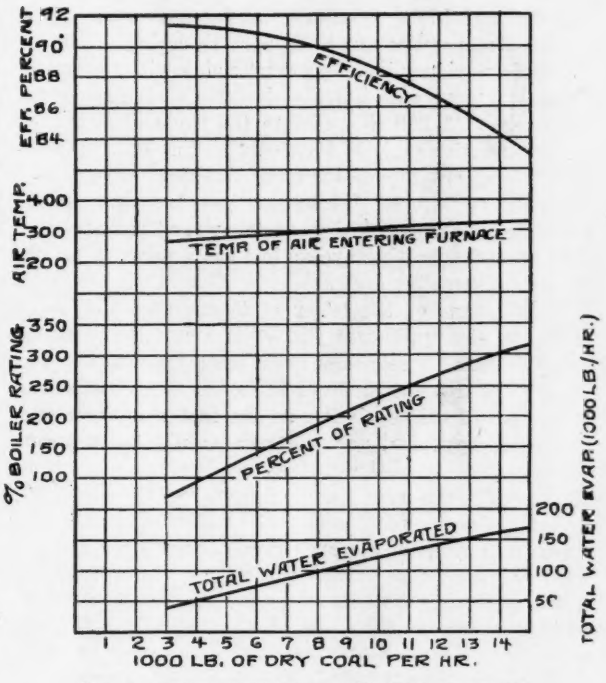


FIG. 9. TEST RESULTS, RICHMOND STATION

friction losses which have been dealt with during the past three or four years.

For use with stokers, preheated air is ordinarily furnished at 300 to 400 deg., since it has commonly been considered that higher temperatures caused mechanical troubles. Figure 9 shows typical conditions in a large stoker-fired plant. Within the past year, however, stokers have been designed to use air at 700 deg. while stoker operation with air at temperatures of 500 to 600 deg. has been carried out successfully in several plants. Recent announcement that air temperatures of 1200 to 1400 deg. are being obtained with air preheaters installed in connection with certain industrial furnaces has proved interesting to power plant engineers.

TERMINAL WAREHOUSE CO., 274 South Water St., Milwaukee, Wis., plans to begin construction of a five-story cold storage and refrigerating plant to cost about one million dollars with equipment. W. Fred Dolke, 1841 Asbury Ave., Evanston, Ill., is engineer.

Economic Limit of High Steam Pressures

We Are Rapidly Approaching a Point at Which Peak Load Stations May Be Preferable to Base Load Installations. By N. E. Funk*

CONSIDERABLE IMPROVEMENT in station efficiency has been accomplished during the past few years by improvements in the design of apparatus, development of steel tube economizers, air preheaters, water walls, deaerators, evaporators, the adaption of the reheat and regenerative cycle, the use of higher steam pressures and temperatures and, in some cases, the new use of other heat conversion mediums such as the mercury vapor process.

Effect of higher pressures and temperatures with various steam cycles can be seen by referring to Fig. 1. The cycle efficiency increases appreciably with high pressures, but more especially in the case of the regenerative cycle. At 200 lb. pressure the cycle efficiency of the regenerative cycle is 3 per cent and at 1200 lb. pressure 7 per cent higher than the Rankine cycle at corresponding pressures. Increasing the temperature of the steam from 700 to 800 deg. has a marked effect on the rankine and reheating cycles, but has a minor influence on the regenerative cycle.

Advantages of the latter cycle are apparent, especially at high pressures and it is generally conceded that the gain in efficiency more than justifies the cost of extra equipment involved in its use. An additional advantage of this cycle lies in the fact that there is a greater energy yield per unit volume of exhaust steam tending to reduce the size of condensing equipment. At 1200 lb. pressure the limitations of the cycle are evident at a maximum cycle efficiency of 47.5 per cent. As used at present, approximately 11 per cent more of the total energy is available with the mercury vapor-steam cycle than with the regenerative cycle at 1200 lb. Nevertheless, the use of any other medium to replace or combine with the steam cycle must be justified in relation to increased costs of installation and operation compared with the thermal saving.

*Chief Engineer, Philadelphia Electric Co. Abstract of a paper presented before the Washington Section of the A. S. M. E.

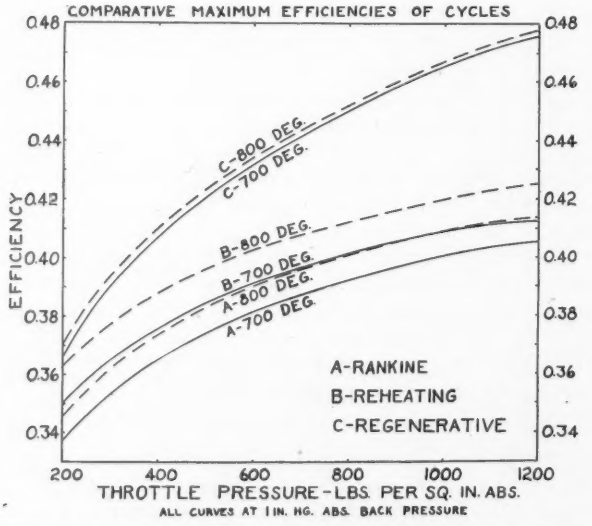


FIG. 1. A COMPARISON OF THREE DIFFERENT CYCLES, SHOWING EFFECT OF INCREASED PRESSURES AND TEMPERATURES

Initial Investment Must Be Justified for the Total Life Period of the Plant

Investment costs of installations, using high pressures and temperatures involving the more complicated cycles, are higher than those of installations using the simple Rankine cycle. These higher costs must be justified by increased economy, not only on the basis of the period of initial operation, but of the total life period of the installation.

For a cosmopolitan center, a typical load curve may be represented, as shown in the left-hand diagram of Fig. 2, the load being expressed as a percentage of the peak, although it may be put in a much more convenient form to use for determining the possible loading of the various generating stations of a large system. This new form is shown in the occurrence curve in the right-hand diagram of the same figure. The ordinates of both figures are the same, but in the second diagram the abscissa is per cent of kw-hr. generated. For each ordinate value there is plotted an abscissa, the per cent of the day's total kilowatt-hours generated at or below the average kilowatt value as indicated by the dotted lines.

If the day's total kilowatt-hours had been generated at 100 per cent load factor, the load curve would be represented by the complete block below the average, or 58.8 per cent kw. in the left-hand diagram, including the shaded area. The occurrence curve would then be the straight, or 100 per cent load factor line, extending from 0 to 58.8 per cent kw. in the right-hand diagram; however, in the actual condition, this shaded area was

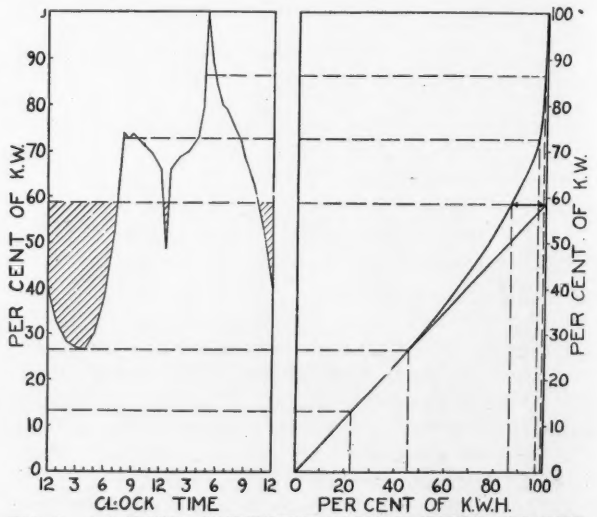


FIG. 2. A TYPICAL COSMOPOLITAN LOAD CURVE AND THE CORRESPONDING OCCURRENCE CURVE

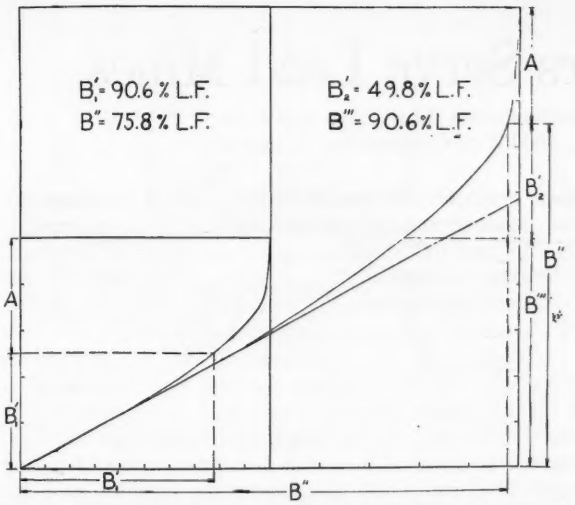


FIG. 3. APPLICATION OF THE OCCURRENCE CURVE TO THE DETERMINATION OF GENERATING STATION EXPANSION

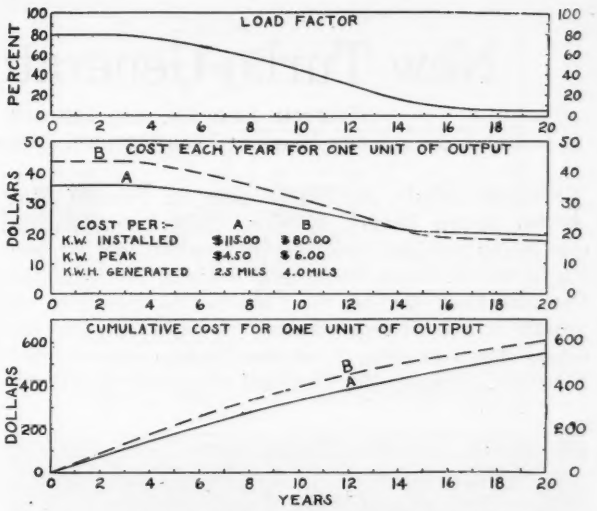


FIG. 4. A COMPARISON OF TWO STATIONS WITH DIFFERENT INVESTMENT COSTS OVER A 20-YEAR PERIOD

not generated, causing the occurrence curve to fall away from the 100 per cent load factor, as indicated by the arrowed line in the occurrence diagram. It should be noticed that all loads up to 26 per cent kw. occur at 100 per cent load factor and fall on the straight line in the occurrence diagram.

Occurrence Curve Facilitates Study of New Stations

Loading possibilities of a generating station may be readily studied, using the occurrence curve as above. Figure 3 shows two curves drawn on the same 100 per cent load factor line. The left-hand curve is just one-half as large as the right-hand one. For a smaller curve assume a system with two generating stations, A and B'_1, each capable of supplying half the load but B'_1 being the more efficient. In this case B'_1 would run as a base load station with a load factor of 90.6 per cent as indicated and A would operate as a peak load station.

Now suppose the system load doubled, as in the larger curve. Station A remains the same and continues as a peak load station, but now supplies only one-quarter of the total kilowatt load. The remaining load could be supplied in several ways: First by enlarging B'_1 with the same type of apparatus, in which case it would become B" and would have the load factor reduced to 75.8 per cent; secondly and more likely B'_1 would remain the same and a more efficient station, B"', would be built to carry the base load.

In this case the station B"' would have a load factor of 90.6 per cent the same as B'_1 and B'_1 would become B'_2 and have the load factor reduced to 49.8 per cent. A third case might apply to large systems having a very sharp peak load. In this case, a peak load station of low investment cost might be built to serve only over the peak period, thus improving the load factors of existing stations.

This discussion has indicated that with a growing system load the load factor of a generating station will decrease with years of service, due to the construction of new, more efficient stations. This fact materially affects the balance of investment and operating cost in choosing a new type of installation.

An estimate of the reduction of load factor on a generating station over a 20-yr. period is shown in the upper curve of Fig. 4. The curves in the middle block show the cost each year for one unit of output for two stations operated at the estimated load factors. Station A is a high investment cost station with low operating cost and station B is a low investment cost station with a high operating cost.

In the Future, Peak Load Stations May Be a Better Investment Than Base Load Plants

In the early years of operation, the low running cost of station A overbalanced the high investment cost and Station A operated at less cost than station B; however, in the later years with low load factor, the reverse was true and B operated at the lower cost. The cumulative cost for the 20-yr. period is shown in the two lower curves with station A proving less expensive for the total period; however, it is possible with certain conditions that the two curves might have crossed, showing station B less costly for the total period.

It appears, from the foregoing study of cycle efficiencies, that we are rapidly approaching a point where it is possible that the additional investment cost may not be warranted in obtaining high operating efficiencies. Until the present time, it has been possible to obtain greater economy with so small an increase in investment cost that systems were warranted in building new stations for base load operation, permitting the older stations to operate over the peak load periods.

As the limit of economy is approached, however, it appears that the differential between new and old station economy may become of so small a value that it would not pay to drop load from the old stations in order to carry base load on the new. In this case, the building of peak load stations with low investment cost might be warranted at intervals as an alternate to the present policy of base load installations.

It is granted that some of the factors mentioned in this discussion are not easy to evaluate, but the time has arrived when they must be carefully considered in all studies relative to new installations if the best balance of economy is to be maintained.

New Turbo-Generators Serve Lead Mines

NATIONAL LEAD CO. AND DESLOGE CONSOLIDATED LEAD CO., EACH IN THE MISSOURI LEAD DISTRICT, INSTALL 4000-KW. CONDENSING TURBINES

IN THE LEAD DISTRICT near St. Francis, Mo., two Brown Boveri, 4000-kw., 3600-r.p.m., straight condensing turbines have recently been put into service; one at the St. Louis Smelting & Refining Works of the National Lead Co., at St. Francis, Mo., designed to operate at 175 lb. gage pressure, no superheat, and the other, shown in Fig. 1, at the Desloge Consolidated Lead Co., Desloge, Mo., designed to operate at 175 lb. gage pressure, 125 deg. superheat. Both machines are for straight condensing operation with a vacuum of 27.5 in. and will utilize steam furnished by boiler plants previously installed. The turbines were made by the American Brown Boveri Corp. at its plant at Camden, N. J., under European designs and patents.

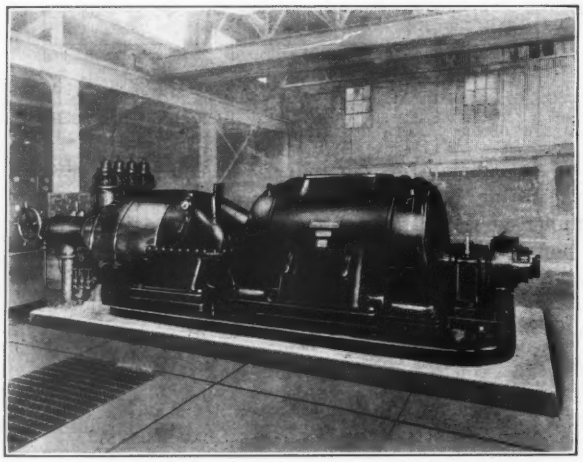


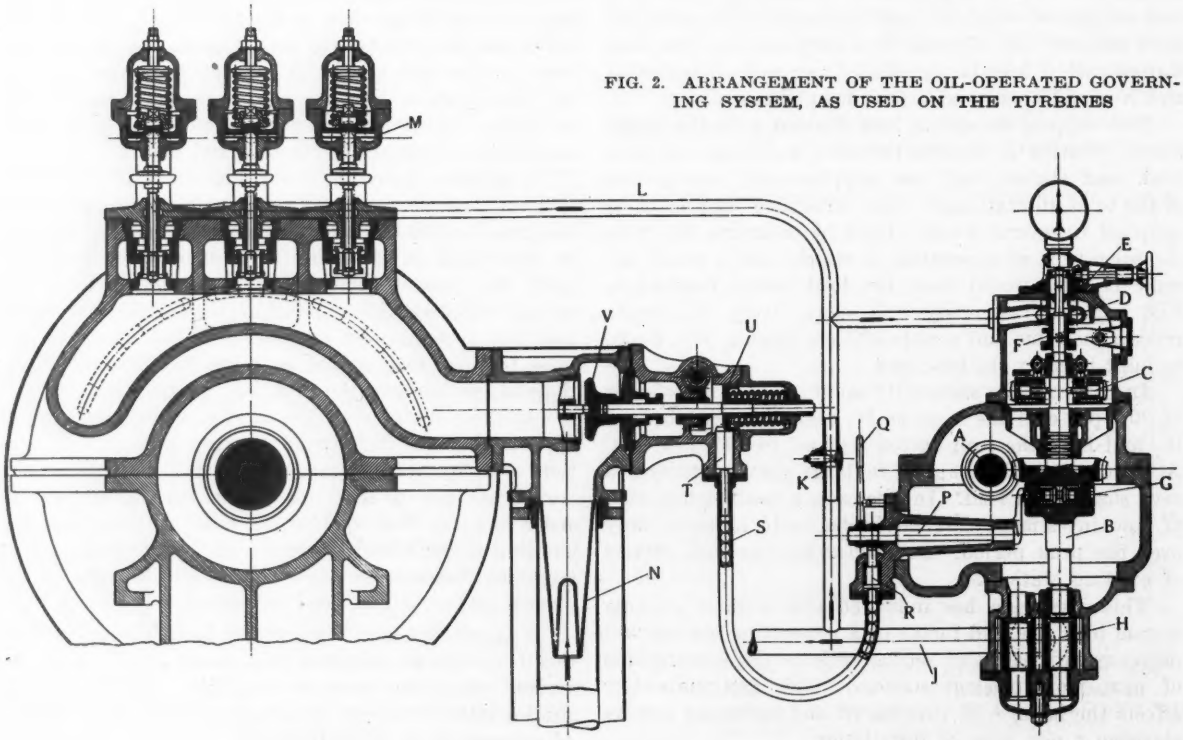
FIG. 1. THE 4000-KW., 2300-V. UNIT INSTALLED IN THE POWER PLANT OF DESLOGE CONSOLIDATED LEAD CO.

As shown by the cross section, Fig. 3, the turbines are of the combined impulse-reaction type, consisting of a double stage impulse wheel and approximately 30 reaction stages. The arrangement of the reaction blading in the form of a cone is for the purpose of giving good flow conditions throughout the machine and has the additional advantage of allowing a blading of reasonable length to be used in the high-pressure portion of the reaction drum.

Wheels making up the rotor are not shrunk on, but utilize a special device, with spring fastening for the purpose of insuring a true concentric position of the wheels under all operating conditions. The axial thrust is equalized by means of a balance piston with a thrust bearing of ample proportion provided to keep the rotor in its position and to take care of the unbalanced thrust at certain load conditions. This thrust bearing, developed by Brown Boveri, works on the same principle as the Kingsbury thrust bearing and is combined with the support bearing on the inlet side of the turbine in order to decrease the length of the unit and facilitate dismantling.

An oil-operated nozzle control governing system with

FIG. 2. ARRANGEMENT OF THE OIL-OPERATED GOVERNING SYSTEM, AS USED ON THE TURBINES



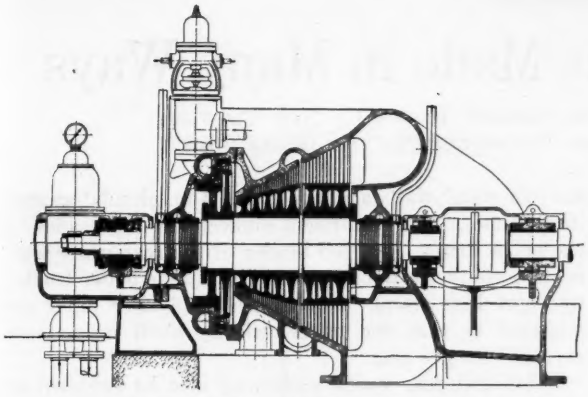


FIG. 3. LONGITUDINAL SECTION OF THE TURBINES, SHOWING FEATURES OF DESIGN

four spring loaded nozzle valves located at the top of the turbine, as shown schematically in Fig. 2, is used. The oil used for governing and lubrication is supplied by an oil pump of the gear wheel type, which is rigidly connected to the governor shaft and produces practically constant oil pressure.

Pressure in the oil line leading to the nozzle valves is under control of the fly-ball type governor, the pressure depending on the load carried by the machine. Springs of the nozzle valves are adjusted to give the required nozzle opening for the various loads. An independent overspeed governor and hand tripping device are provided, arranged to actuate directly the main inlet valve of the turbine, which forms an integral part of the machine.

Both generators are wound 3-phase, 60-cycle, and connected to the turbines by means of flexible couplings. The St. Francis unit is a 4900-kv.a., 6600-v., and the Desloge unit a 5175-kv.a., 2300-v. machine. Cooling air in both units enters at the bottom of the generator casing and is forced through the machines by ventilator fans mounted on the shaft at both ends of the rotor. The air discharge is at the bottom, but separated from the intake in such a way that easy connection to air cooling equipment can be made in case a closed air cooling system is later installed.

Each unit is provided with a direct connected exciter, the characteristics of which allow the entire regulation of the generator to be done exclusively by regulating the current in the exciter field. In addition, they are equipped with main field rheostats to be used for separate excitation from busbars. Both units are equipped with Brown Boveri quick acting voltage regulators, which were described in detail on page 937 of our Sept. 1, 1927, issue.

Voltage Regulators Are Used with Both Generators

An elementary diagram of connections for the voltage regulator is shown in Fig. 4. The split phase winding is connected across terminals of the alternator with the rheostat, g, in series with the field winding of the exciter. The cycle of operation is as follows: Assuming that the generator is fully loaded, the contact segments will then take up a position similar to the one shown in Fig. 4, in which a great part of the resistance is short circuited. This position does not change

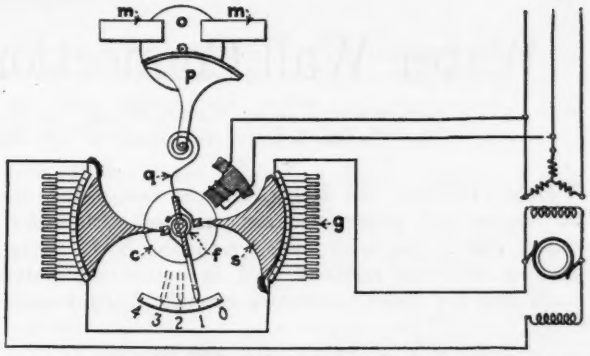


FIG. 4. DIAGRAM OF CONNECTIONS OF THE VOLTAGE REGULATOR FOR A SINGLE GENERATOR

as long as the voltage remains constant, because an electric torque produced in the drum, c, is counterbalanced by the torque in the spring end. A drop in load tends to raise the voltage and the smallest increase is immediately followed by an increase in the electrical torque so that the system becomes unbalanced.

As a result, the segments are displaced to the left so that the mechanical torque, now increased by the torque of the recoiled spring, q, again equals the electrical torque. The resistance inserted in the field circuit by the displacement of the sector is as much in excess as that which will be necessary to adjust the excitation to the new load conditions. In this way, the inherent inertia of the magnetic field is rapidly overcome and the voltage is restored to normal. This causes the sectors to go back to the right, but since the tension of the recoiled spring has been reduced, because of the following up of the aluminum disc, which, at the other end, is connected to the geared quadrant, they come to rest at the position which corresponds to the position of correct excitation.

United States Civil Service Commission announces an open competitive examination for chief steam-electric engineman, applications for which must be on file with the Commission in Washington not later than May 26. Entrance salary is from $2400 to $3000 a year and a probationary period of 6 mo. is required. Duties are to be responsible for the operation and maintenance of a large building or a group of buildings having an extensive mechanical equipment, including boilers, heating system, electrical generating equipment and auxiliaries. Competitors will be rated on practical trade questions, education, training and experience. Full information can be obtained from the Commission at Washington or at the post office or custom house in any city.

Report of the United States Geological Survey shows that, during 1927, 575,000 hp. was added to the developed hydraulic power of the country in plants of public utility power companies. The total as of Jan. 1, 1928, was 12,296,000 hp. installed, covering some 15 per cent of the potential water power. California ranks first among the states with 1,993,000 hp. of water wheels, New York second with 1,779,000 hp. and Washington third with 707,000 hp.

Water Wall Connections Made in Many Ways

INCREASED USE OF WATER WALLS AND WATER SCREENS BRINGS UP NEW PROBLEMS IN WATER WALL CONSTRUCTION AND THEIR CONNECTION TO THE BOILER PROPER

PRACTICALLY all large furnaces now being designed and constructed are provided with water-cooled walls. Inquiries made by the N. E. L. A. regarding different methods used in connecting water walls into the boiler circulation brought many replies.

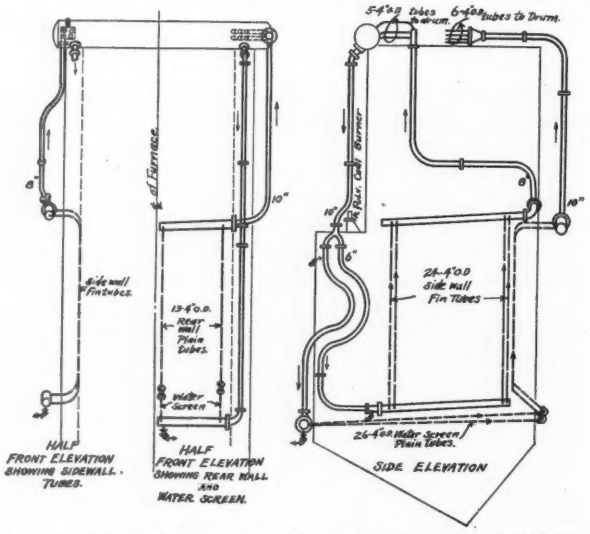

Side wall Fin tubes.
13-4"O.D. Rear wall Plain tubes.
Water screen
HALF FRONT ELEVATION SHOWING SIDEWALL TUBES.
HALF FRONT ELEVATION SHOWING REAR WALL AND WATER SCREEN.
28-4"O.D Side Wall Fin Tubes
26-4"O.D Water Screen Plain Tubes.
SIDE ELEVATION

FIG. 1. IN THIS SYSTEM A 10-IN. DOWNCOMER IS TAKEN DIRECTLY OFF EACH END OF THE BOILER DRUM

Except for the manner of water supply from and direct return to the main drum, no uniformity appears to exist in the method of these connections. Connections used for 2520 sq. ft. of water wall screen with an 18,756-sq. ft. cross-drum boiler are shown in Fig. 1.

A 10-in. downcomer is taken off each end of the boiler drum. These are split, one 8-in. lead supplying one-half of the water screen and the rear water wall, both of which have plain tubes and a 6-in. lead supplying the fin tube side wall surfaces. Each 8-in. riser from the side wall surfaces is split into five 4-in. tubes to enter the boiler drum. Each 10-in. riser from the rear wall surfaces is split into six 4-in. tubes to enter the drum.

Another method used in connecting 3160 sq. ft. of water screen to front, rear and side walls of a 17,440-sq. ft. cross-drum boiler is shown in Fig. 2. Instead of directly connecting the downcomers to the drum, six 4-in. tubes are used. From each 10-in. downcomer, two 4-in. tubes supply the common header for the front water wall and four 4-in. tubes supply each side wall bottom header. The 10-in. downcomer is then reduced to 8 in. for the water screen header supplying 19 plain screen tubes, which in turn supply 38 fin type rear wall tubes.

Both the top and bottom front wall headers have 38 fin tubes and three 4-in. circulating pipes outside the furnace, while four 4-in. risers connect the top header with the boiler drum. The top and bottom headers of the side water walls also have three 4-in. circulators and 27 fin tubes. Six 4-in. risers connect this top header to the boiler drum. The top header of the rear water wall is connected with the bottom of the uptake boiler header by eight 4-in. risers. Downcomers and riser pipes are designed so that the water velocity shall in no case exceed 5 ft. per sec.

Side and rear water walls may also be supplied as shown in Fig. 3, drawn to show the arrangement of connections for 22,920-sq. ft. boiler. The walls are supplied as shown by an 8-in. downcomer from the end of the main drum. The connection between this drum and each vertical downcomer is by means of five 4-in.

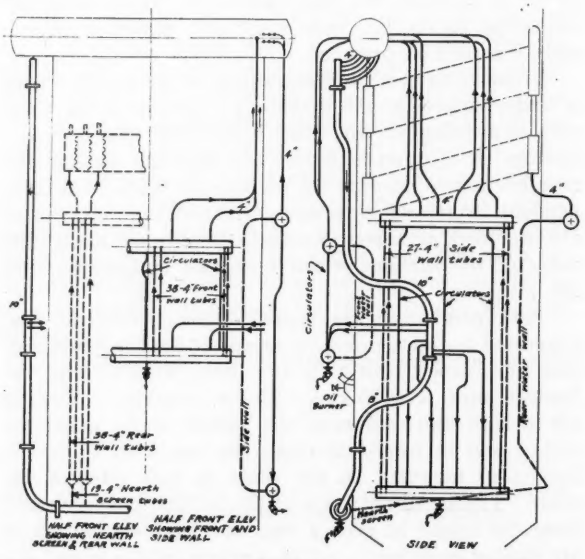

Circulators
38-4" Front wall tubes
38-4" Rear Wall Tubes
19-4" Hearth Screen Tubes
HALF FRONT ELEV SHOWING HEARTH SCREEN & REAR WALL
HALF FRONT ELEV SHOWING FRONT AND SIDE WALL
27-4" Side wall tubes
SIDE VIEW

FIG. 2. IN THIS ARRANGEMENT A 10-IN. DOWNCOMER IS CONNECTED TO THE BOILER BY SIX 4-IN. TUBES

tubes which are tapped in the main drum at different points. The vertical downcomer extends below the boiler room floor and branches at right angles into two lines.

One branch line runs toward the uptake end of the boiler to supply the rear water wall, while the other branch line runs toward the front of the boiler and then upward so that it connects with the lower side water wall header. A similar arrangement is provided for the vertical downcomer on the opposite side of the boiler, thus resulting in one feed to the bottom header on the corresponding side wall and a feed to the rear water wall from each vertical downcomer except toward the end of the side wall where it is necessary to have bends in some of the tubes in order to provide clearance for the fire box doors.

Top and bottom side wall headers are located outside of the boiler setting, necessitating a right angle bend for each tube at both bottom and top. Four 4-in. flexible tubes connect the return pipes to the main boiler

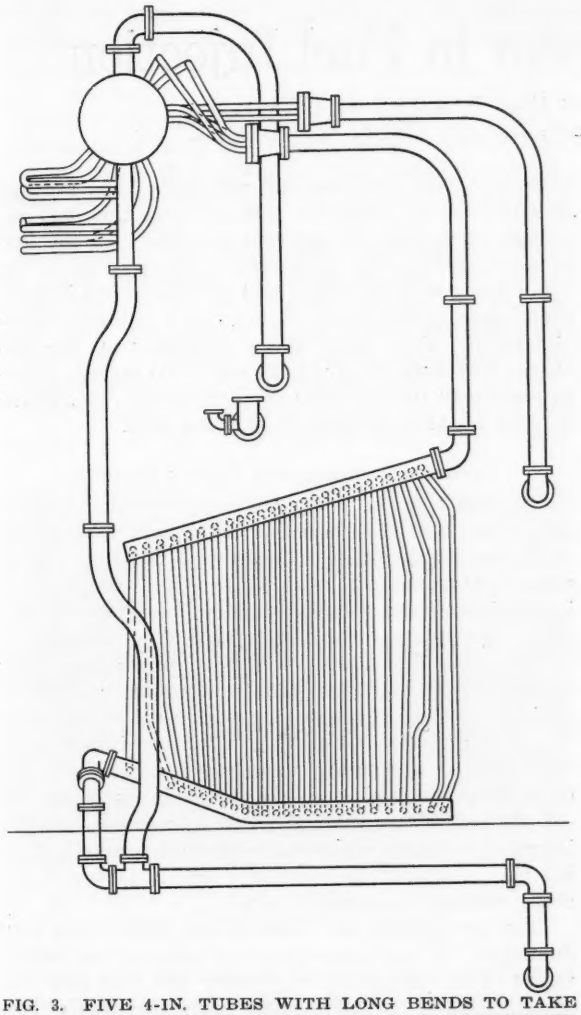


FIG. 3. FIVE 4-IN. TUBES WITH LONG BENDS TO TAKE CARE OF EXPANSION SUPPLY AN 8-IN. DOWNCOMER FROM EACH END OF THE BOILER DRUM IN THIS ARRANGEMENT

drums. There are, however, two return pipes at each side of the boiler, one from the side wall and the other from the corresponding end of the rear water wall. The size and arrangement of the rear water wall tubes are similar to those of the side wall tubes. The rear water wall extends down to the rear wall of the clinker pit to the level of the clinker rolls, but the tubes are here covered with cast-iron blocks provided with air openings, thus forming a cast-iron surface.

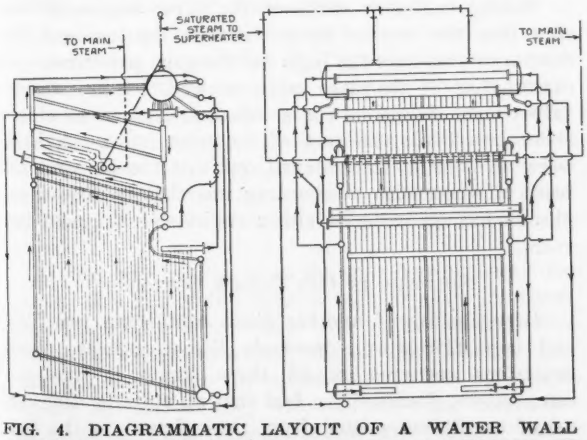


FIG. 4. DIAGRAMMATIC LAYOUT OF A WATER WALL CIRCULATING SYSTEM, SHOWING THE DIRECTION OF FLOW IN THE DIFFERENT PORTIONS OF THE FURNACE WALL

Riser Pipes Enter Boiler at About Normal Water Level

Diagram of the water wall, water screen circulating system installed in a recent station is shown in Fig. 4.

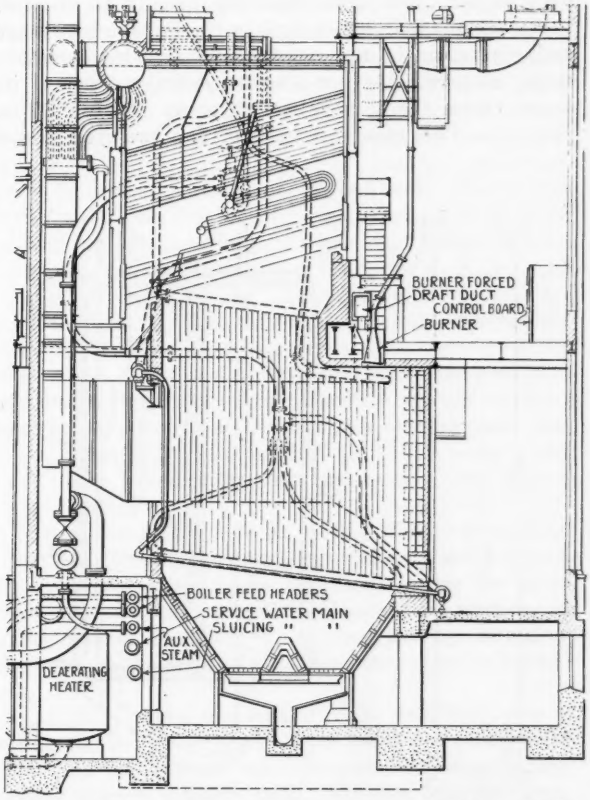


FIG. 5. WITH THIS ARRANGEMENT A SINGLE DOWNCOMER FROM EACH SIDE OF THE BOILER DRUM FEEDS THE SIDE WALLS, WATER SCREENS AND REAR WALL

In this case the bottom header for each side wall is supplied from a separate header connected to the boiler drum by five branch pipes, while the water screen is supplied from a header running lengthwise of the boiler drum. Side wall returns are divided between two headers, while the front wall and arch screen discharge to the same header and the return joins that of the shorter side wall header before entering the boiler. The returns from both systems enter the boiler at about the normal water level.

Still another arrangement is shown in Fig. 5 where a single downcomer on each side of the boiler is connected to the boiler drum by nine branch pipes. This downcomer later branches into three pipes, the first supplying the water screen and through the water screen the rear wall and the second two supplying opposite ends of the bottom header for the side walls. Returns from various parts of the system are through six pipes, three on each side of the boiler and the return into the boiler through a number of smaller pipes which are connected to the boiler drum in two longitudinal rows somewhat above the normal water line.

Air Compressor Behavior in Fuel Injection

PROPER INSTALLATION AND CARE INSURE GOOD OPERATION OF COMPRESSORS USED FOR FUEL INJECTION WITH DIESEL ENGINES. BY J. J. McDOUGALL

INVESTIGATION OF fires and explosions occurring in the air-compressor systems of Diesel engines, ranging in power from 750 to 2250 br.hp., shows that with proper precautions these can usually be avoided.

In one plant in which fires in the low-pressure stage and explosions in the intermediate and high-pressure stages occurred, the low-pressure cylinder received its supply from the scavenging air pump at about 4 lb. pressure. This plant consisted of two two-cycle Diesel engines of 1250 br.hp. each having three-stage air compressors compressing 230 cu. ft. of air per min. to 1250 lb. per sq. in., the stage pressures being: low pressure 65, intermediate pressure 325 and high pressure 1250 lb.

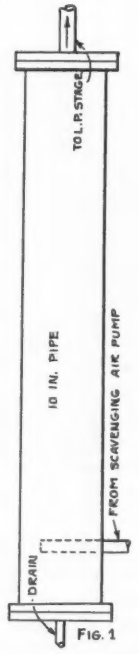


FIG. 1

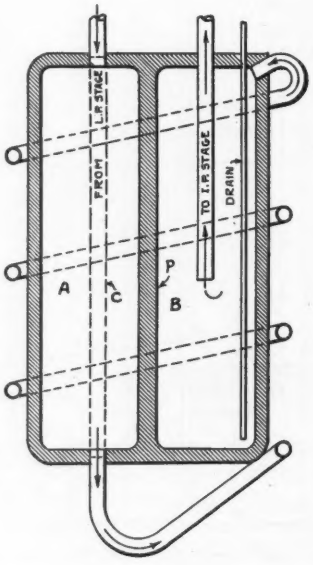


FIG. 2

FIG. 1. ARRANGEMENT OF AIR COOLER AND CLEANER SET-UP OUTSIDE OF ENGINE ROOM ON NORTH SIDE OF BUILDING, MAKING POSSIBLE SUPPLY OF CLEAN, COOL AIR

FIG. 2. ARRANGEMENT OF LOW-PRESSURE INTERCOOLER IN WHICH AIR ORIGINALLY ENTERED CHAMBER B, FILLING IT ALMOST FULL OF CARBON; IMPROVED BY INSTALLATION OF PIPE C

Investigation showed that the scavenging pump was of inferior design because first, it allowed a great quantity of lubricating oil to be sucked in from the crank case and second, while it compressed the air to only about 4 lb. pressure the discharge air temperature was about 190 deg. F., representing a rise of 100 deg. F. over normal. This air at 190 deg., while saturated with lubricating oil, was then compressed in the low-pressure stage, making conditions ideal for fires and explosions.

First, disconnecting the low-pressure stage from the scavenging pump and running the suction line to atmosphere was tried, but the result was that a blast pressure of only 900 lb. could be obtained and this was not enough to develop 20 per cent overload. So the low-pressure suction was connected up as in Fig. 1, the result being that clean and cold air was drawn into the compressor cylinder and all fires and explosions were eliminated. Also, after seven months' run, the discharge valves were coated with very little carbon, whereas previously the indicator denoted them to be starting to plug up after running only three days.

IMPROPER INSTALLATION CAUSES TROUBLE

Investigating further, it was found that the low-pressure intercooler was installed backwards so that the drain was on the hot side, hence very little oil and no water was drained out, both being forced over into the intermediate stage. Referring to Fig. 2, instead of discharge air entering chamber A and going through the cooling coil, thence into chamber B, where practically all the water and oil would be deposited and easily drained off, originally the air actually entered chamber B and, being very hot and heavily charged with lubricating oil, this chamber was about seven-eighths full of carbon, six good sized shovelfuls being taken out. All the rest of the oil and water was forced into the intermediate stage whose valves were continually fouling up. Cleaning the intercooler and installing it correctly removed the trouble here.

The low-pressure and intermediate intercoolers were duplicates. It was noticed that air entering the suction valves of the high-pressure cylinder was very hot. An investigation of the intermediate intercooler showed that the partition P, Fig. 2, was cracked throughout its entire length, thus allowing a great deal of the hot discharge air to pass directly into the cold side so that very little water and lubricating oil were deposited but passed over into the high-pressure stage, fouling the valves and causing excessive pressures and temperatures which resulted in violent explosions; this was overcome by installing pipe C as shown dotted in Fig. 2.

Taking indicator cards of the three stages, it was seen that the suction pressures were too low and the discharge pressures too high for the gage pressures. An examination of the plate valves showed that the suction valves were defective, for at opening they were closed about two-thirds the area of the inlet holes. A little work on a lathe straightened out this trouble and the result of the entire overhauling was that no fire or explosion has occurred on either engine for the past two years.

SULPHUR IN GAS CAUSES CORROSION

Investigation of another plant containing two 1250 and two 2250-br.hp., two-cycle Diesel engines, where explosions occurred in all three stages of the air-compressors, disclosed the fact that an entirely different set of conditions existed from those found in the first mentioned plant. First a great deal of exhaust gas

highly charged with sulphur was being sucked into the low-pressure stage of the compressors on the large engines that took air from the engine room. Considerable exhaust gas found its way into the scavenging pumps, thence into the air compressors of the small engines, resulting in a rapid eating out of the cooling coils which, if not changed every few months, burst. Second, due to a poor lubricating system, the compressors were being flooded with oil, resulting in the valves being plugged up every few days.

In this case, the suction pipe was pointed towards the power cylinders. On these engines, the piston trunks run out of the cylinders several feet and on heavy loads considerable exhaust gas escapes into the engine room. This gas is, of course, drawn into the scavenging pumps and air compressors and, as the fuel used ran as high as 7 per cent sulphur, the exhaust gas was heavily charged with sulphur gases which, when

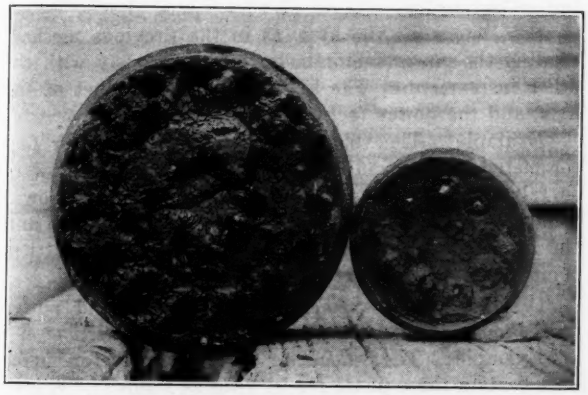


FIG. 3. CARBON DEPOSITS AFTER A FEW DAYS' RUN UNDER DEFECTIVE LUBRICATION

combined with the water in the compressed air, formed sulphuric acid, which rapidly ate away the coils. The remedy in this case was to run all suction pipes outside the engine room to a fresh air supply. Installation of oil wiper rings on the piston trunks of the air compressors and of force feed lubricators for each stage, remedied troubles due to poor lubrication and stopped the valves from plugging up.

Locating Troubles

Water jackets of intercoolers should be made of boiler plate and be provided with large weak-plates as experience has shown that this type of jacket merely ruptures under the force of an explosion without throwing loose pieces about the plant and such breaks may be repaired by electric or torch welding. An intercooler has sometimes been kept in service by removing the burst coils, if the remaining coils appear to be in good condition but this is done only when no spare coils are on hand.

At the left in Fig. 3 is shown a low-pressure discharge valve and at the right, a high-pressure discharge valve after only a few days run under the defective lubricating system described above. An indicator diagram will show when the valves start to foul up. Gages will not do this but they will indicate when valves are leaking or sticking. Temperatures will indicate which valve is defective. A little attention will keep the air compressor systems reasonably safe while a little neglect may result in the necessity of shutting down the plant for repairs.

Slagging Screens Prove Effective

MATERIAL ASSEMBLED on slagging screens by the N. E. L. A. indicated a large number of different types in service, all of which appear to assist in reducing troubles due to slag accumulation.

Three companies report improved slag conditions with slag screens formed by leaving out alternate tubes in the first row while one company reports satisfactory results with a screen formed by placing the second row of tubes directly over the first row. Another stated that prior to removing the entire second row of tubes the boiler had to be shut down every two weeks but since making this change the boilers are able to operate continuously. In one installation the lower three rows of tubes were unstaggered. The effectiveness of this arrangement has not as yet been definitely determined. Other reports state that in a new installation every other tube in the first three rows is left out. This has some advantages but, in any case, a certain amount of hand work is necessary, in addition to soot blowing above this zone. In another installation of ten boilers every other tube in the four bottom rows was omitted and proved to be effective.

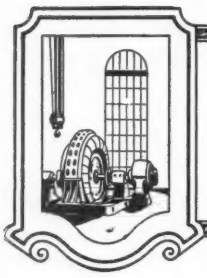
Two theories are held as to why slag is formed on the tubes. One theory maintains that slag will not form on tubes if combustion is completed before the gases reach them as slag accumulations consist of particles of sticky coal which adhere to the tubes, leaving the ash on the tubes in the form of slag after the carbon is burned out.

Another theory contends that the trouble is due to ash in the molten or sticky form being fastened on the tubes and that the ash need not necessarily contain any carbon when it attaches itself. On this basis the question as to whether slag will or will not form is purely a matter of the fusion point of the ash and the temperature of the ash particles when they reach the tubes.

Conclusions of another company regarding this subject are that "a large gas passage at the slag screen is important in helping to keep the velocity low and with a greater amount of surface exposed to radiant heat the gases are cooled to a point where the dust does not adhere to the tube and cause choking of the draft at that point."

UNIVERSITY OF SOUTHERN CALIFORNIA, Los Angeles, Calif., announces that 23 yr. after the inauguration of the first course in engineering at the University, a college of engineering has been created. Philip S. Biegler, professor of electrical engineering at the University for the past 5 yr. has been appointed acting dean. The new college will open in September and will be made up of five major divisions with separate chairmen.

EVEN A HUMBLE worker, to be of any value, must have self-respect.

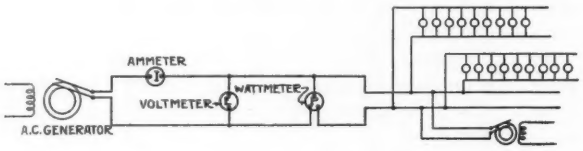


ELECTRICAL MACHINERY FOR LIGHT AND POWER

Reactive Component in A. C. Circuits

PART IV. DETERMINATION OF THE WATTLESS COMPONENT. EVALUATION OF TEST DATA. BY V. E. JOHNSON

BEFORE A POWER factor survey, such as described in the previous article of this series, can be made, it is necessary to have means for measuring the various quantities involved. The amount of wattless current can be determined by several methods, using wattmeters, ammeters, voltmeters and power factor meters. These are all based on the two fundamental formulas:



CONNECTIONS FOR DETERMINING POWER FACTOR OF AN A. C. CIRCUIT BY MEANS OF VOLTMETER, AMMETER AND WATTMETER

$$\text{(1)} \qquad \text{Power factor} = \text{Kw.} \div \text{Kv.a.}$$

$$\text{(2)} \qquad \text{Kv.a.} = \frac{\text{Volts} \times \text{Amp.} \times \text{K}}{1000}$$

where volts are measured between phase wires, amperes are measured in the phase wires and K is a constant determined by the phase of the system. For single phase K = 1, for 2 phase K = 2, and for 3 phase K = 1.73.

METHODS OF DETERMINING POWER FACTOR

Power factor can be determined by one of the following methods:

A. Determine the kv.a. by reading simultaneously the volts and amperes and using the proper value of K. Determine the kw. at the same instant by reading the wattmeter. Applying formula (1) above gives the power factor. The wattless component will be

$$\text{(3)} \qquad \text{Wattless kv.a.} = \sqrt{\text{Kv.a.}^2 - \text{Kw.}^2}$$

Example: The voltmeter, ammeter and wattmeter readings in a certain three-phase feeder were as follows: 2300 v., 100 amp., 300 kw. The kv.a. from formula (2) would be 398 and the power factor from formula (1) 300/398, or 75 per cent. The wattless component would be, from formula (3), $\sqrt{398^2 - 300^2} = 261$ kv.a. The nature of the load would indicate whether this is leading or lagging.

B. Determine the kv.a. as in the previous method, reading the power factor meter simultaneously with the other instruments. The kw. will be the product of the kv.a. and the power factor.

Example: The voltmeter, ammeter and power factor meter readings on a certain three-phase feeder were as follows: 2300 v., 100 amp., and 75 per cent power factor. The kv.a., using formula (2), would be 398 and the kw. 75 per cent of this, or 300 kw. The wattless component would be determined as before.

C. Read simultaneously the wattmeter and power factor meter. Then the kv.a. would be kw./p.f.

Example: The wattmeter and power factor meter on a certain three-phase feeder read as follows: 300 kw., and 75 per cent p. f. Then the kv.a. will be 300/0.75, or 398. The wattless component will be determined as before.

Values used in the foregoing calculation may be those at any selected instant, or may be the average of a number of readings taken during any period. Station records may also be used. With a fluctuating load such readings are subject to many errors, but with a sufficient number of tests these cancel each other so as to give a fairly accurate average. They are, however, tedious to obtain, and if based on simultaneous observations, require two or more men.

Curve drawing instruments afford a much more convenient method of making such studies and charts representing even very fluctuating loads can, with a little practice, be evaluated by inspection. By carefully synchronizing the clocks on these instruments, the power factor at any instant, or the average during any interval, may readily be determined.

TWO WATTMETER METHOD

In addition to the more or less obvious methods of determining the magnitude of the wattless component, as outlined in the previous paragraphs, there is the so-called "Two Wattmeter Method," which is, however, applicable only on three-phase systems where the power is measured by two-element meters of the polyphase type, or by two single-phase meters.

With this method of metering, the energy transmitted is equal to the algebraic sum of the integrations

of the two elements of the polyphase meter, or of the two separate single-phase meters. Similarly, with indicating instruments, the power is equal to the algebraic sums of the individual indications of either the elements in the polyphase type, or of the separate single-phase instruments. This algebraic sum is obtained by computation in the case of the two single-phase meters, or mechanically in the polyphase type.

At unity power factor, the two elements read equal amounts but under other conditions their indications differ. At 50 per cent, one of them stands still and below this it reverses so that its reading must be subtracted from that of the other in order to obtain the net power. There is at all times a definite relation between the power factor and the ratio of these single-phase readings. It is immaterial whether the single-phase readings are the integrations of meters of the watthour type or indications of the ordinary switchboard or portable variety.

This relation is expressed by the following formula:

$$\text{Tan } \theta = \sqrt{3}\,\frac{M_1 - M_2}{M_1 + M_2}$$

where θ is the angle of lag, and M_1 and M_2 the readings of the two meters. M_1 is taken as the larger reading and is considered to be positive at all times, while M_2 is the smaller and may be either plus or minus, as the case may be.

Example: Assume readings as follows on two single-phase wattmeters:

$$M_1 = 350 \qquad M_2 = 100$$

Substituting in the formula above

$$\text{Tan } \theta = 1.73 \times \frac{250}{450} = 0.962$$

From a table of natural trigonometric functions, it will be seen that a tangent of 0.962 corresponds to a cosine of 0.72, thus indicating that the power factor is 72 per cent.

Had the reading of M_2 been negative, the calculation would have been as follows:

$$\text{Tan } \theta = 1.73 \times \frac{450}{250} = 3.12$$

From a table of natural functions, it will be seen that a tangent of 3.12 corresponds to a cosine of 0.30, thus indicating that the power factor is 30 per cent.

If the determination of power factor is to be based upon the registration of watthour meters, the most convenient method is that based upon the comparative lengths of time required by them to make any convenient number of revolutions, and to apply the following formula:

$$\text{Tan } \theta = \sqrt{3}\,\frac{T_2 - T_1}{T_2 + T_1}$$

where θ is the angle of lag and T_1 and T_2 the time required for a given number of revolutions of the meters M_1 and M_2.

Example: Assume that for 10 revolutions of the disc the time required was $T_1 = 65$ sec. $T_2 = 100$ sec. Substituting in the formula

$$\text{Tan } \theta = 1.73 \times \frac{35}{165} = 0.367$$

From a table of natural functions, it will be seen that a tangent of 0.367 corresponds to a cosine of 0.94, thus indicating that the power factor is 94 per cent.

The "Handbook for Electrical Metermen," published by the National Electric Light Association, contains the following table which expresses the relations between the two readings directly as power factor. The headings of the columns have been modified to correspond to the symbols used in the foregoing formulas.

VALUE OF COS θ (POWER FACTOR) FOR M_2/M_1 OR T_1/T_2

M_2/M_1 Positive									
M_2/M_1	P.F.	M_2/M_1	P.F.	M_2/M_1	P.F.	M_2/M_1	P.F.	M_2/M_1	P.F.
.847	.99	.554	.89	.381	.79	.246	.69	.117	.59
.790	.98	.525	.88	.367	.78	.233	.68	.104	.58
.747	.97	.507	.87	.353	.77	.220	.67	.092	.57
.712	.96	.490	.86	.339	.76	.207	.66	.079	.56
.681	.95	.473	.85	.325	.75	.193	.65	.066	.55
.654	.94	.457	.84	.312	.74	.181	.64	.053	.54
.629	.93	.441	.83	.298	.73	.168	.63	.039	.53
.605	.92	.425	.82	.285	.72	.156	.62	.026	.52
.583	.91	.410	.81	.272	.71	.143	.61	.013	.51
.563	.90	.396	.80	.259	.70	.130	.60	.000	.50
M_2/M_1 Negative									
.013	.49	.154	.39	.312	.29	.498	.19	.729	.09
.027	.48	.169	.38	.329	.28	.519	.18	.756	.08
.041	.47	.183	.37	.346	.27	.540	.17	.784	.07
.054	.46	.199	.36	.364	.26	.562	.16	.811	.06
.068	.45	.214	.35	.382	.25	.584	.15	.840	.05
.082	.44	.230	.34	.400	.24	.606	.14	.870	.04
.096	.43	.246	.33	.419	.23	.630	.13	.902	.03
.110	.42	.262	.32	.438	.22	.654	.12	.933	.02
.125	.41	.279	.31	.458	.21	.678	.11	.967	.01
.139	.40	.295	.30	.478	.20	.703	.10	1.000	.00

Applying these tables to the examples given above, the following solutions are obtained:

Example 1: Where $M_1 = 350$ and $M_2 = 100$, $M_2 \div M_1 = 100 \div 350 = 0.286$ which, from the table, corresponds to 72 per cent power factor.

Example 2: Where M_2 was negative, $M_2 \div M_1 = -0.286$. This, from the second table, gives a power factor between 30 per cent and 31 per cent.

Example 3: Where $T_1 = 65$ sec. and $T_2 = 100$ sec., $T_1 \div T_2 = 65 \div 100 = 0.65$. This corresponds to a power factor of 94 per cent in the table.

Some confusion may arise in using this method due to the fact that the polarity or sign of M_2 must be known; however, the nature of the load will usually indicate whether the power factor is above or below 50 per cent; if above, the reading is positive, while below it is negative. In extreme cases, it may be necessary to control this phase relation artificially, by either unloading or heavily loading the induction motors on the line, so as to make the power factor very low or else quite high, so as to obtain a positive indication of the meter polarity. If the motors are unloaded by throwing off the belts or other means, it is safe to assume that the angle of lag is great enough to cause a backward reading of one meter. As load is applied, this meter will gradually drop to zero, and finally reverse as the power factor goes above 50 per cent, after which its sign is positive. Similarly, if a balanced

heating or lighting load is being metered, it is safe to assume that both meters read plus. On polyphase meters, single-phase readings are obtained by disconnecting one element, usually by opening the potential circuit.

Average Effective or Integrated Power Factor

The average power factor over considerable periods of time may be obtained by using two integrating watthour meters, A and B, connected so that meter A reads the kilowatt-hours, while meter B reads the reactive kilovolt-ampere-hours, the latter being the integration of the wattless component over the time interval selected.

Example: Assume that meters A and B are set at zero at the beginning of the test period, and that at the end they read 750 and 950, respectively. The average power factor for the elapsed time will be calculated as follows:

$$\text{Kv.a.-amp.-hr.} = \sqrt{950^2 + 750^2} = 1210$$

$$\text{P.f.} = 750/1210 = 62 \text{ per cent}$$

If tables of natural trigonometric functions were available, this same result could have been obtained as follows:

$950/750 = 1.26 =$ tangent of 52 deg. 40 min.

which is the angle of lag. The cosine of this angle is 0.62, which agrees with the result previously obtained.

Assuming that the time interval was 10 hr., the average indicated kv.a. would be 121; this should check with the result obtained from voltmeter and ammeter readings.

There are available at the present time so-called kv.a. meters which read kv.a.-hr. directly, and which also give the kw-hr. This simplifies the calculations to some extent, and also affords a ready means for checking the output on the basis of kilovolt-amperes instead of kilowatts.

It has already been stated that the wattless component is costly because of wasted capacity, increased losses and impaired service. In evaluating the data obtained by the above methods, the figures should be interpreted with reference to their effect on these conditions.

The indicating or curve drawing instruments are used in determining the magnitude and character of the loads, also the time of their occurrence. The latter is exceedingly important, for a wattless current, even if quite heavy, wastes relatively little capacity if it comes at an "off peak" time.

Integrated readings furnish no information as to the time element, nor as to the demand, therefore they are not of much value in determining how much capacity is being wasted. On the other hand, they do afford accurate data on the average condition and this is useful in calculating the losses.

A true composite picture of the power factor conditions can best be obtained from tests made with both types of instruments; expensive changes in equipment should not be undertaken without a complete and accurate knowledge of all the existing conditions, obtainable only by a study based on all available information.

If power is purchased and corrective measures are intended to reduce the billing under the power factor clauses, the wording of these should be studied in order that their provisions may be met with the least expense. For example, if the rate is based on the average value obtained from the integrations of two watthour meters, the corrective equipment need be only of sufficient size to reduce the reactive registration to the required value.

Example: If the 950 reactive kv.a.-hr. in the previous example had been registered during a 10-hr. interval, the power factor could have been made to average 100 per cent by supplying (leading) 95 kv.a. continuously during that period. If, however, the rate were based on peak power factor or some equivalent value, the corrective equipment would have to be rated to take care of the conditions at that time.

Electricity---What It Is and How It Acts

Part II. The Electron. Fundamental Conceptions of the Atom. Mechanism of Electrification by Friction

IN THE PRECEDING article, we traced briefly the history of the electron theory of electricity and described the principal events which led to the discovery of the electron by its behavior in the vacuum tube. We now come to a more detailed consideration of the electron itself and its relation to ordinary electric phenomena with which we are familiar.

Everybody is more or less familiar with simple experiments having to do with electrically charged bodies. Since the time of Thales it has been known that amber when rubbed with fur or silk will attract small bits of paper. Sheets of paper if rubbed on a dry winter day will crackle and when pulled apart will give off minute sparks. Sometimes, it is only necessary to walk across the carpets in our homes, to enable us to draw sparks from radiators and other grounded objects.

What is the explanation of these strange phenomena? How does a body become charged and why? Wherein does a charged body differ from one that is not charged?

The answers to all of these questions are to be found in the modern conception of matter—in the fact that every atom of matter is made up of minute electric charges—tiny particles of positive and negative electricity, in fact. What we know of these particles of electricity has been obtained almost entirely from the action of the negative particle, commonly known as the electron. Originally, the term electron was used merely to denote the unit electric charge without regard to whether its sign was negative or positive but in late years the electron has come to mean only the negative charge. For the positive electron the word proton has been coined.

Properties of the Electron

All electrons are similar, regardless of the kind of atoms from which they are obtained. Thus an electron from the hydrogen atom acts precisely the same as the electrons from atoms of helium, iron, gold or oxygen. It is definite in amount, always being exactly the same, and so far as we know cannot be divided into smaller parts.

Electrons, all being alike and having charges of the same sign, tend to repel each other with relatively enormous forces. Two electrons placed at a distance of 1 cm. (⅜ in.) from each other in a vacuum will repel each other with a force of 1.16×10^{-19} dynes. This, of course, is an exceedingly small force but it is tremendous when considered relative to the size and weight of the electron. It has been estimated[1] that if it were possible to collect 2 grams of pure electrons and to form them into two equal spheres each weighing one gram and if these spheres were held 1 cm. apart as shown in Fig. 1, they would repel each other with a force of 320 million million, million, million tons!

To form a conception of an electron in terms of anything with which we are familiar, is practically impossible. Its mass, in technical language, is 8.8×10^{-28} grams and its electric charge 1.59×10^{-19} coulombs. This, of course, means nothing to the ordinary mind familiar only with such units as the watt, the ampere and other practical quantities, and it is only when such practical units as amperes are expressed in terms of electrons that we can begin to form some idea of their astonishing smallness. Consider, for example, the quantity of electricity that flows through an ordinary 16 candle power carbon filament electric lamp in one second, worth about 1/100,000 of a cent at ordinary rates.[2] If the three million inhabitants of a city like Chicago should begin to count the electrons passing through such a lamp in one second, and were to keep on counting them out at the rate of two a second, and if no one of them ever stopped to eat, sleep or die, it would take them just about 16,700 yr. to finish the task.

In attempting, however, to form a mental picture of the electron, it is best not to associate in mind the idea of a small particle having definite size and mass in the ordinary sense, because the size and mass of an electron are things about which we must speak somewhat reservedly. The electron makes itself known only by virtue of the electric and magnetic field created by its presence and the thing that we call mass in an electron may be merely a form of electromagnetic energy. For the present, however, and for purposes of explanation, we shall continue to speak of them as definite particles, regardless of what their absolute nature may be.

From the electron point of view, a negatively charged body is one having more than its normal number of electrons, and a positively charged body is one having less than its normal number. A normal atom is not charged, because the number of positive electric charges in such an atom is exactly balanced by the number of negative charges. Such an atom exerts no attractive or repulsive force upon other atoms.

The Structure of the Atom

In the light of modern research, a neutral atom consists of a positively charged center, called the nucleus, around which are grouped a number of electrons, the combined negative charge of which is just sufficient to neutralize the excess positive charge of the nucleus. The nucleus itself consists of closely grouped numbers of positive electrons and negative electrons, but there are always more positive electrons or protons, than negative electrons. It is this excess of protons over electrons that gives the nucleus its positive charge.

The electrons which are external to the nucleus are separated from it and from each other by relatively large distances, despite their smallness. Perhaps as good a picture of an atom as may easily be formed is obtained by a comparison with our solar system. The distances between the sun and planets are very large compared to the diameters of any of the planets or even the sun itself. If we now imagine the sun to be extremely small as compared to the size of the earth and then imagine all the distances and sizes to be reduced proportionately, until the system is invisible with even the most powerful microscope, we have a possible picture of a simple atom. In this comparison, it is necessary to make the sun smaller than the earth because the nucleus is small compared to the electron. Offhand, this may sound absurd because we have said already that the nucleus is composed of numbers of positive

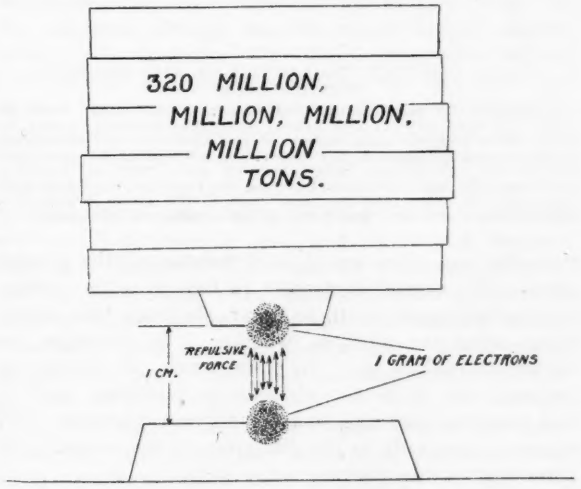


FIG. 1. IF IT WERE POSSIBLE TO COLLECT 2 GROUPS OF PURE ELECTRONS AND DIVIDE THEM INTO TWO GROUPS 1 CM. APART, THEY WOULD REPEL EACH OTHER WITH FORCE OF 320,000,000,000,000,000,000,000,000 TONS!

and negative electrons, but experience seems to indicate that the union of two or more protons with one or more electrons is a smaller particle than is a single isolated electron. It seems that in the nucleus, the electrons and protons may merge in a union so close that their combined size is less than the electron alone.

The simplest atom is that of hydrogen. This consists of only one proton and one electron. The two elements are probably whirling about each other in space much like a rapidly whirling dumbbell except that there is no rigid connection between the ends. The diameter of this atom is about two hundredths of a millionth of a centimeter but this is about one hundred times as large as the diameter of the electron.

The nucleus itself is less than one three millionth the size of the electron, in fact, the nucleus of the hydrogen atom is a sphere so small that, if it were magnified to the size of a pin's head, that pin head would, on the same scale of magnification, become magnified to the radius of the earth's orbit around the sun, a sphere some 185,000,000 mi. in diameter.

Other atoms are built up in the same way, except

[1]Fournier, "The Electron Theory."
[2]R. A. Millikan, "The Electron."

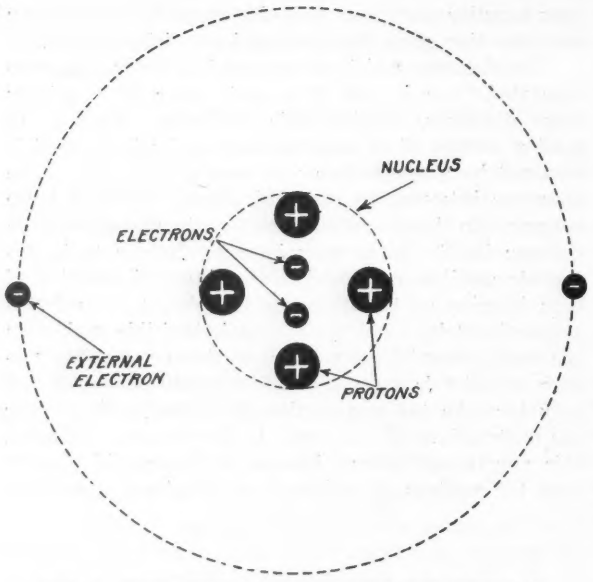


FIG. 2. CONVENTIONAL MODEL OF THE NEUTRAL HELIUM ATOM

NOTE: In considering this diagram, one must keep in mind the fact that in the actual atom the nucleus would be very much smaller than either of the two external electrons. This may sound absurd, but experiments seem to indicate that this is so. Evidently, when two or more protons combine with one or more electrons to form the nucleus, the attractive forces are so great that the total mass of the group is squeezed into a space smaller than any of the component elements.

that they are more complicated because of the greater number of external electrons. In fact, it is the number and arrangement of these outer electrons that determines what the atom is, whether it is hydrogen, or copper or radium, etc. In other words, all substances, are made up of the two elementary quantities, positive and negative electrons, and the difference between substances is due only to the difference in the number and arrangement of electrons in the atom.

Next in simplicity to the hydrogen atom is the atom of helium. This consists of a nucleus and *two* external electrons. The nucleus contains four protons (positive electrons) and two electrons, thus providing the excess

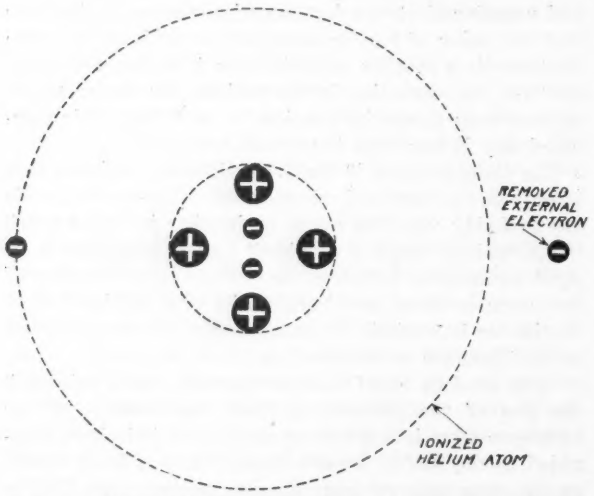


FIG. 3. CONVENTIONAL MODEL OF AN IONIZED HELIUM ATOM

NOTE: This, it will be obvious, is the same arrangement shown in Fig. 2 except that one external electron has been removed, leaving the atom as a whole with an excess of positive charge.

of two protons to account for the two external electrons. A conventional model of a neutral helium atom is shown in Fig. 2.

Atoms of other substances have a more complicated nucleus and a larger number of outer electrons. The atom of sodium, for instance, has 11 outer electrons, that of sulphur 16 and of oxygen 8. Uranium, the heaviest of all elements, has 92 external electrons. There are exactly 92 chemical elements, all of which may be arranged in a series with hydrogen at one end and uranium at the other, so that each one will differ from the two on each side of it by the same amount of electrical charge on the nucleus and by one external electron.

The orbits of the outer electrons draw closer to the nucleus as the latter becomes heavier, but they always remain at the same distance for the same substances.

With this conception of the atom, it will be obvious that the atom, instead of being solid matter, as was once thought, is in reality mostly space. The electrons composing the atom may be compared to a few grains of

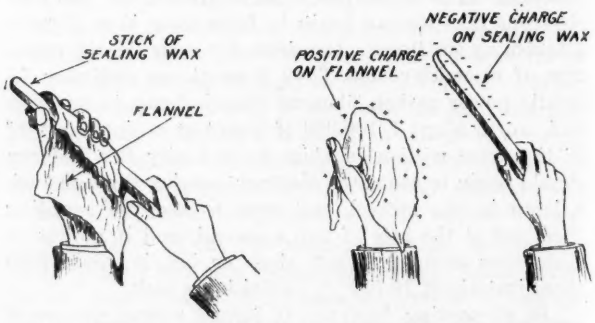


FIG. 4. WHEN A STICK OF SEALING WAX IS RUBBED WITH FLANNEL, THE WAX ACQUIRES A NEGATIVE CHARGE AND THE FLANNEL A POSITIVE CHARGE

sand in a large cathedral, the cathedral representing the outer boundary of the atom. The electrons fill the dimensions not because of their bulk but rather because of their energy. Oliver Lodge once said that electrons occupy the otherwise empty region of space which we call the atom in the same sense that a few scattered but armed soldiers can occupy a territory—occupying it by forceful activity, not by bodily bulk.

Having presented a picture of a simple normal (neutral) atom, we are now in a position to discuss what happens when a body is electrically charged. Suppose that by some means or other the balance between the negative and positive charges in an atom such as is shown in Fig. 2 is destroyed—suppose we remove one of the external electrons as shown in Fig. 3. The atom is now unsatisfied, so far as the balance between positive and negative charges is concerned. The excess of one proton in the nucleus gives the atom a positive charge. In this state the atom is said to be ionized.

If the removed electron (or any electron) is permitted to return to the atom, the balance of charge is restored and the atom is once more neutral.

It is evident from this that a positively charged body is one which has been deprived of some of its normal number of electrons. In the same manner, a negatively charged body is one in which the atoms have acquired more than their normal number of electrons. When a piece of sealing wax is rubbed with dry flannel, the wax becomes negatively charged and the flannel positively

charged. Evidently, in the act of rubbing, the friction between the flannel and the wax must have rubbed some of the electrons off the atoms composing the flannel and left them on the surface of the wax.

Since the surface atoms or molecules (a molecule is a group of atoms) of the flannel are now deficient in electrons and the surface atoms or molecules of the wax have an excess, if the wax and the flannel are left together after being rubbed, there will be a readjustment of electrons, the excess of the wax returning to the deficient atoms of the flannel.

So it is seen that the phenomena of electrically charging and discharging bodies is fundamentally very simple. To understand it, it is merely necessary to have a simple conception of the structure of an atom, and to know that a neutral atom must always have just as many positive charges as it has negative charges.

In the very next article we shall take up in greater detail the actual structure of more complex atoms. Electrical phenomena are closely related to the atomic structure of matter, and a knowledge of the latter is essential to a proper understanding of the former.

Reminiscences of an Elevator Inspector

EXPOSITION OF TROUBLES ENCOUNTERED IN ACTUAL PRACTICE AND OF HOW THEY WERE CORRECTED. BY S. H. SAMUELS

ELEVATORS which "always ran all right before" often develop troubles which have caused engineers to scratch their heads after searching high and low to discover the cause. The trouble shooter coming on the ground will often ask the engineer many questions so that he may eliminate possibilities which might be the cause of the trouble for which he was called to correct. Some of these interrogations, with their consequent replies by the engineer, are asked in order that the problem may be attacked from the most probable location and some of them are asked before the inspector even sees the installation. The engineer will sometimes become exasperated at these questions, telling the man called in, "I tried this and it doesn't do any good—I tried that, without results."

These attempts at correction by the engineer who knows his business and his explanation of the results are all helpful for elimination of possible causes. The trouble man is bringing in an entirely new viewpoint and an open mind to the plant, in contrast to that of the engineer's, which has become somewhat befuddled because of unsuccessful attempts at correction. Troubles with electric elevators will, in many cases, be found in the control circuit, or as a consequence of control contactors getting out of adjustment.

To illustrate: In one case, a passenger elevator when running full speed would not slow down properly before reaching the upper or lower floor, consequently going into the limit switches. This was only occasionally, however. Many trips were made and everything seemed to operate the way it should. Then, suddenly, when running full speed in the down direction, it would hit the bumpers and throw out the lower limit switch, the operator being powerless to control it from the car. The engineer's statement was that the emergency switch in car would stop the elevator motion if only the operator had sufficient time to use it after realizing that he had lost control. Getting the car out of the limits, it would apparently operate all right for a while, only to go into the lower limit switch again or perhaps into the upper limit switch, the engineer stating that it had gone into the upper limit switch once, under a similar condition.

When the inspector came on the job, he questioned the engineer to get from him the nature of his trouble and incidentally brought out the above stated peculiarities of operation. It may be stated that this passenger elevator was a three-landing car in a bank. At the basement landing was the safety deposit department, on the first floor were the banking offices with a high celling and dome, while on the top floor was located the bonding department at a level where the dome began. The distance between the main and top floor was nearly 60 ft., while the distance from main floor to the bottom landing was only 11 ft., the normal speed of this elevator being 350 ft. per min. The traffic was usually between the main and top floor or the main floor and basement. The cases of running full speed into the lower limit were usually in making the main floor to basement run. The operator was an elderly man and it later developed that he threw his controller on the full, depending on the automatic slow-down of the car before he stopped at either terminal landings. It may be stated further that there was no slow-down device on top of car or any series of slow-down switches in the hatchway which were operated by the car. The only automatic slow-down was the machine slow-down, operated by the drum shaft screw, which slow-down was set to be effective only 3 ft. from terminal landings.

First, the main switch was opened and, after noting the condition of their carbons, all the control contactors were tried by hand. Entering the car, the inspector operated it cautiously at first, before turning it over to the operator. Standing before the control board, he had the operator handle the car. It was then noted that the operator used only two positions of his controller—full and stop. When he threw it on full, the speed would automatically step up and the high speed contactor would slam in with a bang. When he stopped, however, it would drop out somewhat sluggishly because the contactor arm was not quite heavy enough below its fulcrum, and because the plunger of this contactor had accumulated a little dirt on its oily surface —which did not help matters any. In addition to these conditions, it was found that the end of the plunger and the core head of its solenoid had been receiving hammer-like blows. This head was unscrewed and a brass washer inserted to prevent the plunger from sticking (when the carbons wore down) on account of the residual magnetism of the core. The core screw was then adjusted for proper throw of the plunger and the machine slow-downs were set to be effective at a greater

distance from terminal landings so that the momentum of the car would not make the machine slow-downs seem ineffective.

Car Would Not Go Into High

Another case of trouble was, in effect, just the opposite of the previous case. This elevator on occasion would not come up to full speed; the car would run up to the top floor, thereafter only to run at next to full speed. Every once in a while, however, it would come into its full speed again after running at the slower speed with the control handle full over. If, however, the car was run to the basement landing while under those speeds, the jinx would be broken and the car would run all right until it started down from the top landing again.

From these actions as explained by the engineer and his statements as to the attempted remedies, the trouble was located in the slow-down switch on top of the car. One of the switch arms of the slow-down device was found to be binding slightly on its shaft, which prevented its return to make proper contact when the car left the slow-down cam at the upper landing. The cam roller was moved in the opposite direction by coming into slow-down at the basement landing and a slight movement of the contactor arm shaft took place which helped close the faulty contactor so that the car ran at full speed again.

Slow Pick-Up

Then there is the case of an elevator picking up speed too slowly and sometimes blowing the fuse. The trouble was looked for in the accelerating contactors on the control board. With the main switch open, the accelerating switch was operated by hand and found to work very stiffly. This switch was of the type having an oil dashpot and the oil bypass valve screw was found to be unscrewed as far as possible without falling out.

Looking about the machine room, a small can was seen on the floor in a corner among the larger cans of lubricating oil, grease for the guide rails and cotton waste. Picking up this can and shaking it showed that it was full. It was labeled Special Dashpot Oil and evidently no attempt had ever been made to use this special oil supplied by the manufacturer of the control board, for the cover was on pretty tightly. The dashpot was taken off the board and noted to be filled with lubricating oil of the consistency ordinarily used for motors. The manufacturers' special dashpot oil was substituted for the lubricating oil, replaced on the control board and the oil bypass valve properly adjusted as judged by manual operation of the accelerating switch. The fuses were replaced and the elevator operated without any further troublesome experiences. This installation was put in service in the late summer months. When the weather got a little colder the lubricating oil in the dashpot increased in viscosity to such a degree that further opening of the oil bypass valve gave little help toward better operation.

Frequently a new elevator installation, hurried for time, leads to carelessness of the installing mechanic with trouble in store for the owner when the job is turned over to him by the elevator company as "completed." On testing the safety device under the car on such a recently turned over job, the safety cable could not be unwound from its drum with two men pulling on the cable. Observation showed no reason for the tightness of the drum, for view was restricted by bumper plate. Removing this plate, it was observed that a short hardwood wedge had been stuck between the safety drum and the channel plates of the sling frame during construction and the direction of the sloping wedge surfaces were such that the harder the safety cable was pulled, the tighter the drum was wedged from turning to perform its proper function.

Sulphur in Gear Case Oil Is Beneficial

The cutting action of the elevator gears may be eliminated by mixing a quantity of powdered sulphur in with the gear case oil. The sulphur has certain qualities which fill up the voids in the machined gear surfaces of the teeth and form a better lubricating film of sufficient body to minimize the cutting action.

Load on an elevator will sometimes be increased because of a dragging brake until it will become difficult to lift a normal capacity load in the car. The remedy is obvious.

Over-counterweighting or under-counterweighting of the car to any large extent will cause the car to slide in one direction only and can be readily distinguished from faulty brakes. If the brake is set up tight enough to counteract the car sliding, the effect which the operator notices in the car as the brake applies will indicate whether the car is correctly balanced.

A sliding car may be caused by other than brake shoe trouble. A freight elevator having a mechanical brake was later provided with hatchway limit switches and contacts on the hoist gates. The operators would sometimes stop the car by opening the gates. Because of the manner in which the solenoid of the new brake was electrically connected, the induction of the windings in the brake solenoid circuit was quite sufficient to hold the brake open for such a length of time as to cause the empty car to slide 2 or 3 ft. in either direction before the brake would apply. With a load in the car, the slide in the down direction would be even greater. Needless to say, the opening of the limit switches had little effect in immediately stopping the car and preventing it from doing damage to the overhead if the upper stop ball on the tiller rope had slipped from its proper position. In this case, the gate contacts and the limit switches opened only one leg of the circuit while the tiller rope control opened both legs of the main circuit, thus the brake was immediately applied when the tiller rope was operated.

Another case of faulty operation of a passenger elevator was found to be caused by a slack cable switch which had become damp and grounded, due to the location of the machine. It would work itself very slightly open, from the jar of the drum and gears, when the car was started. It would then draw an arc and the elevator would run at half speed because the current supplying the motor was limited to that drawn through the resistance of the arc. The balance of the crossarm of the slack cable switch and the switch proper was such that when the elevator was stopped, this switch would close again.

(To be continued)

Gould Street Generating Station

BALTIMORE'S NEW PLANT DESCRIBED IN PAPERS BEFORE A. I. E. E. REGIONAL MEETING

THREE PAPERS on the Gould Street Generating Station of the Consolidated Gas, Electric Light & Power Co. were presented at the Regional Meeting of the American Institute of Electrical Engineers held in Baltimore, Md., on April 17 to 19. One of these papers, dealing with a description of the plant, was prepared by A. S. Loizeaux; another, on the design studies of the plant, by F. T. Leilich, C. L. Follmer and R. C. Dannettel; and the third, on operating experiences at the plant, by A. L. Penniman, Jr., and F. W. Quarles. All of the authors are associated with the Consolidated Gas, Electric Light & Power Co.

Gould Street Station, which began operation in January, 1927, is located in the City of Baltimore on the Patapsco River, an arm of the Chesapeake Bay. This site was formerly the power plant location of the Baltimore Electric Co. but the plant has not been in operation since 1918. The site, however, is highly desirable, as its nearness to important load centers enables energy to be distributed by underground cable at 13,200 v. without transformation. The plot measures 405 ft. by 635 ft. and is of sufficient size to supply load growth for perhaps 10 yr.

In the present installation are one generator and two boilers, the second unit, however, comprising one generator and one boiler, being nearly ready for service. Automatic control is provided for the electric drive of boiler auxiliaries, electric auxiliaries being used throughout the plant. Both the 250-v. exciter and the 460-v. house generator are mounted on the main generator shaft. The switch house is of the isolated phase construction with vertical operation of switches. Actual costs are given for the first unit with estimated costs for the completed plant, resulting in costs for the completed plant of $88.00 per kw. for normal output and $80.00 per kw. for maximum output.

As the power house is located on the water's edge, the coal unloading tower is placed about the center of the bulkhead line. Coal is transported by belt to the pulverizing plant, the buildings of the former generating plant being used to house the pulverizing equipment.

West Virginia and Central Pennsylvania coal fields supply the fuel for the Baltimore power houses over three railroad systems. A differential of 25 cents per gross ton exists in favor of the water delivery of coal, as compared with rail delivery. The result of this differential is that, in all of the three plants, coal is received by water delivery.

Three sides of the furnace are water cooled by fin-tube surfaces backed by special tile, rock wool insulation and steel casing. The front wall is of firebrick, cooled by the preheated secondary air admitted to the furnace through ports at 16 levels in this wall. A water screen interconnected with the rear wall circulating system protects the inclined floor of the furnace which forms the ash hopper.

Primary air, used to convey powdered fuel from the screw feeders to the burners, is a mixture of preheated air tapped from the secondary duct and tempered with room air. Primary air is supplied by two fans per boiler, connected on the discharge by an air bus, which makes any fan available for either boiler. Two forced draft fans per boiler furnish the secondary air taken

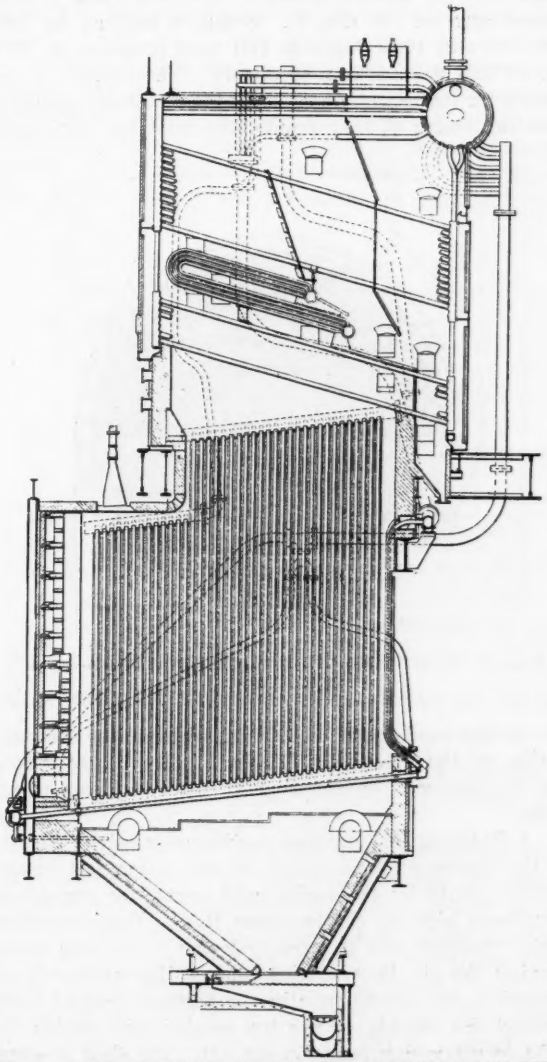


FIG. 1. CROSS SECTION OF BOILER SERVING 36,000-KW. TURBINE

from the room and discharge to a plenum chamber directly ahead of a C-type plate preheater mounted above the gas outlet of the boiler. Tertiary air is taken from the secondary air duct for admission around the burners.

Use of one boiler for a 36,000-kw. turbine with only one additional boiler as a spare unit marks an advance in plant design. Each steam generating unit has a maximum output of 520,000 lb. per hr. at 450 lb. drum pressure and 725 deg. F. superheater outlet temperature, which is sufficient for about 46,000-kw. turbine

capacity. Reserve capacity gained by increased size of boiler auxiliaries, even at some sacrifice in normal operating economy, was found to be more economical than the addition of spare boiler units. Four turbines will ultimately be supplied by five boilers.

The turbine is a 13-stage Rateau impulse machine of 36,000-kw. capacity and drives the main generator through a flexible coupling. It is a modified form of a turbine of lower normal rating of the non-bleeding type. The initial stages, however, have been opened up to pass the additional steam used in bleeding. Steam is supplied at a normal pressure of 390 lb. and a total temperature of 700 deg. F. Steam is bled at the 3rd, 5th, 8th and 10th stages at full load pressures of 193, 99, 30 and 9 lb. abs., respectively. The turbine is designed for highest efficiency at 25,000-kw. load and when bleeding steam at four points, the unit can produce a

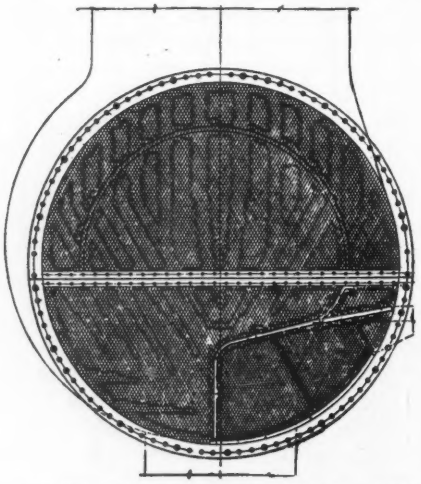


FIG. 2. INLET END TUBE SHEET FOR 30,000-SQ. FT. CONDENSER

net station send-out of 36,000 kw., which is the company rating of the machine. A considerably larger output can be produced by bleeding at the two lower points only.

A 30,000-sq. ft., two-pass condenser is bolted directly to the bottom of the turbine exhaust casing and is supported partly by the casing and partly by springs on structural piers on the basement floor. The circulating water passages are so arranged that the cooler water leaving the air de-vaporizing and cooling section is returned in the second pass in the annular ring of tubes around the outside of the top section with which the exhaust steam first comes in contact. The shell is eccentric with the tube sheet, providing a steam belt which, on one side, extends to the hot well, which prevents excessive condensate depression. The tubes are rolled into both tube sheets, a new feature of design that is discussed in other papers.

Make-up feedwater is supplied by a low heat level interstage evaporator of the vertical single-effect recirculating film type using city water as feed at a maximum rate of 10,000 lb. per hr., corresponding to approximately 2.5 per cent of the total full load turbine steam flow. Fifth stage steam is used and the vapor is condensed in the evaporator condenser.

The supply of fuel and air to the boilers and the removal of gas is controlled by automatic equipment which governs the speed of the forced draft fans, induced draft fans and coal feeders. There is a separate control panel for each boiler. From this panel, the boiler operator controls auxiliary equipment and, with the aid of signal lights and meters, can tell at any time the operating condition as regards pressures, steam flow and electric power requirements for the various boiler auxiliaries. The electric circuits controlling the fans, feeders, etc., have been interlocked to shut down the equipment automatically in the event of failure of any part of the apparatus which might result in explosive mixtures in the furnace.

Preliminary Studies

Load studies clearly showed the need of additional 62.5-cycle generating capacity in 1927. As a result, a single unit station of approximately 35,000 kw. was authorized. The major features to be settled before equipment specifications could be prepared and detail design work started were: Steam pressure and temperature; number and size of steam generators; type of firing—stokers or pulverized fuel; heat cycle or working heat balance; the most economic design of condenser; auxiliary drive—electric or steam.

It is interesting to note that the estimated cost per kilowatt of a 250-lb. station was 4 per cent greater than for the higher pressure and the over-all economy of a 400-lb. installation was 6.5 per cent better. Studies of relative costs of 600 and 700 deg. F. equipment showed that the improved economy of the higher temperature would justify the slightly increased cost of superheaters and added thickness of high temperature insulation. A maximum drum pressure of 450 lb., with 725 deg. F. temperature at the superheater outlet, was selected. This corresponds to 390 lb., 700 deg. F. at the turbine throttle.

Boiler specifications called for working pressure in the drum of 425 lb. gage and total heating surface of 26,500 sq. ft. The contract as awarded specified operation up to 520,000 lb. of steam per hr., which corresponds to approximately 550 per cent of rating, based on the total boiler and furnace heating surface. The trend of fixed and operation cost records of representative stations showed fixed costs as an increasing percentage of total costs and it was obvious that operating and kilowatt investment costs would be reduced if a small number of large steam generating units designed to operate efficiently over wide ranges of rating could be used. The experience up to that time indicated that water-cooled walls made it possible to operate at high ratings and over a wide range.

Many of the newer plants were using pulverized fuel but it was not obvious that the advantages of this type of firing were such that it should be adopted without careful study. Operating engineers of plants using the two types of firing were consulted and the merits of each carefully weighed. Proposals on stokers and pulverized fuel were obtained and economic set-ups, covering both fixed and operating costs, prepared. Although pulverized fuel investment costs were higher, when the merits of the two systems—tangible and intangible—were carefully considered, it was finally decided to adopt the central system of pulverized fuel firing.

A primary consideration was the selection of a heat cycle that would result in the lowest total cost, when both fixed and operating charges are included. Numerous set-ups were prepared and economies calculated. Each showed that four-stage bleeding and air preheating would yield a greater return on investment than two or three bleeding stages combined with an economizer and preheater. The four-stage bleeding cycle has a further advantage of an approximate increase of 10 per cent capacity at only a slight drop in economy when operating under peak or emergency conditions with the two top-stage bleeders shut off.

Electric drive was selected for the auxiliaries. Some of the factors influencing this decision were:

1. Elimination of small high-pressure steam lines and exhaust lines.
2. Easier control of the heat cycle, as the steam requirements of turbine-driven auxiliaries are not necessarily a direct function of the generator output.
3. Relatively high economy of shaft-driven generators, as compared to individual turbine drive. The steam per kilowatt-hour requirement for the auxiliary generator is the same as that of the main unit.
4. Flexibility and reliability of electric motors and their control.

Operating Experiences

In the operation of the plant, some troubles developed due to the use of wet coal, which were overcome by heating the make-up air by means of high-pressure steam so as to obtain the maximum temperature. This permits of using apparatus that is much more compact and reduces to a minimum the amount of fine coal that is lost in the vented air. The mill dryer is not effective in drying the coal until it enters the mill and this, of course, does not help the flow of coal to the mill. High moisture, however, has caused no appreciable difficulty in feeding the mill since the grid dryers have been removed.

The amount of power used in the grinding and transporting of the pulverized coal averages approximately 19.6 kw-hr. per ton of 2000 lb. The expenditure for the maintenance of pulverizing equipment has been approximately 13.9 cents per ton.

With the coal-feeding equipment originally installed, it was impossible to reach the maximum designed capacity, part of the fault being insufficient motor speed. Sufficient coal, however, could not be supplied after the motor speed was increased to that designated. New screws, having a considerably greater capacity, were furnished for one boiler. These screws caused flooding to take place at lower ratings, resulting in very dense smoke and, in one or two cases, in the loss of much coal to the ash hopper. Also, these screws had so much capacity that it was considered advisable to abandon them and hob out the original screws. Flooding also took place on these modified screws and to eliminate this, spring-loaded disks were applied to the discharge end of the screws to provide a uniform resistance to the coal being fed. These very successfully reduced the pulsations experienced with the feeders having greater capacity than the original.

Changes have been made in the burner design with respect to what is termed the tertiary air, i.e., the heated air which is forced downward around the burner nozzle. These changes have been made with the idea of producing a longer downward sweep of the flame with less and hotter primary air. The present indications are that the new arrangement is exceedingly beneficial.

High Rating Caused Slagging

Some difficulties have been encountered with slagging of the lower rows of boiler tubes. This slagging usually occurred after the boiler had been carrying about 400 per cent rating continuously for 48 hr. or longer. Little trouble was experienced when less load was carried at night than in the daytime and it has been noticed that much slag which had accumulated when operating at high rating fell off when the rating was reduced for several hours. On one of these occasions, when a high rating had been maintained for longer than 48 hr., an attempt was made to cause the slag

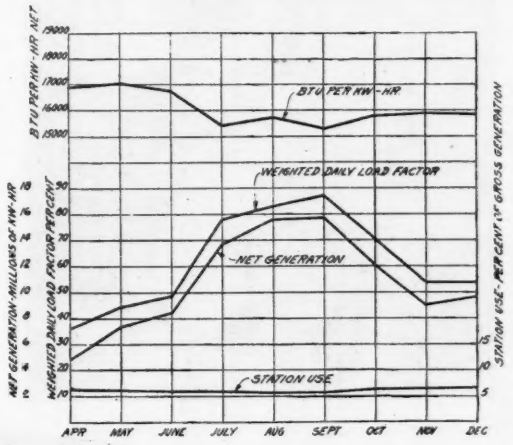


FIG. 3. MONTHLY PERFORMANCE AT GOULD STREET IN 1927

to drop by increasing the excess air, but this apparently had little effect. A shot-gun was fired at the slag but was found to have negligible effect.

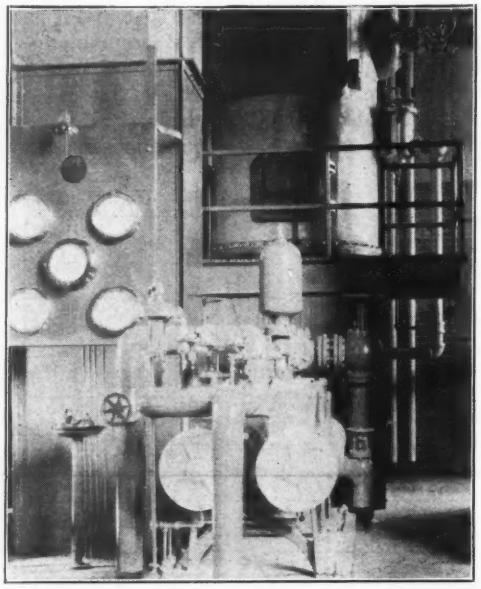
Soon after starting the plant, it was determined that the moisture content of the steam leaving the boiler drums was higher than desirable. The boiler manufacturer has developed and installed a new type of baffle which has produced excellent results. This improvement should be of much benefit in maintaining of cleaner surface on the interior of the superheater tubes, since the moisture, of course, carries solids in solution. It also will reduce the duty on the superheater for a given temperature of steam leaving the superheater.

The main condenser, while of somewhat radical design in that the tubes are rolled into the tube sheet at both ends, has given but little trouble. Few noticeable leaks have occurred. Only one leak of consequence has shown up, this one apparently being due to a condenser tube not being rolled in at one end, the flare serving to keep the leakage down for a long time.

Actual performance has approached fairly close to the anticipated and it is apparent that, when the air heater performance is improved and the effect of the recent increase in steam temperature is realized, the anticipated performance will at least be met.

University of Detroit War Memorial Conceals Heating Plant Chimney

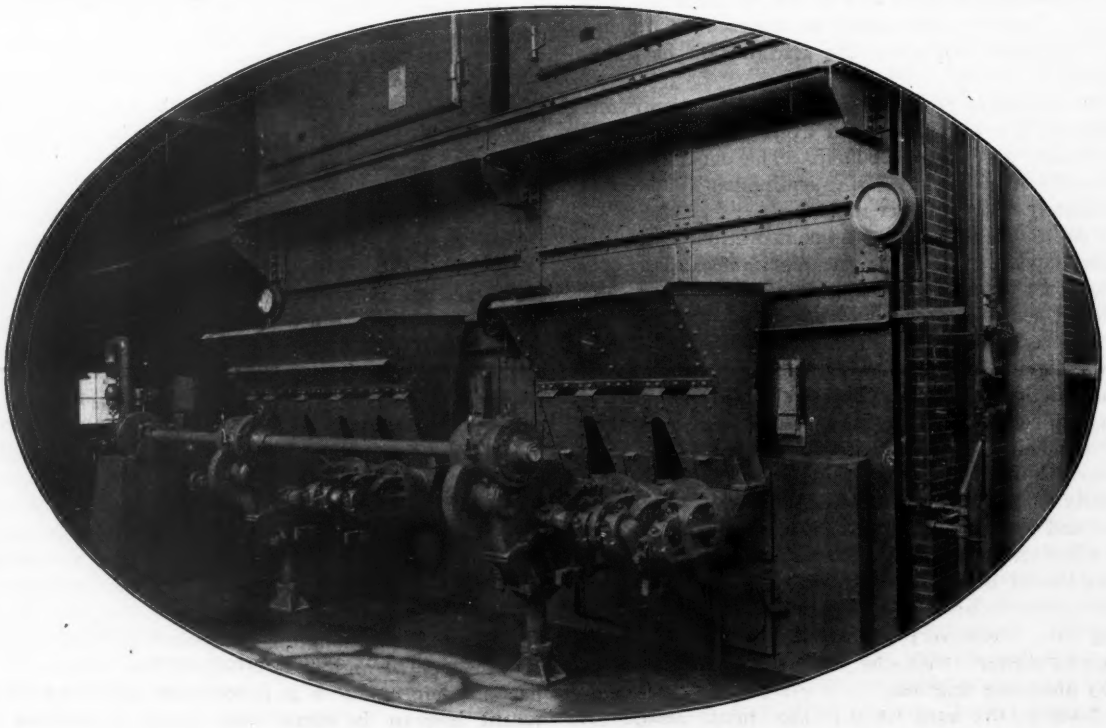
TO MAKE the boiler plant chimney harmonize with the group of buildings recently erected by the University of Detroit, Detroit, Mich., the architects combined the boiler plant and chimney with a memorial tower to the students of the university who died in the World War. The plant at present supplies only steam for heating and laboratories but it is the intention later to double its size so that a turbo generator and auxiliaries can be installed. Charles A. Faulkner is chief engineer of the university.



Steam is generated at 125 lb. pressure by two boilers: a 300-hp. and a 500-hp. cross-drum water tube boiler, fired by a 3-retort and a 5-retort underfeed stoker respectively. A fan in the basement supplies forced draft for these, while a combustion control system regulates stoker and fan speeds.

Returns from the heating system and trap discharges are sent by tilting traps to the 3000 gal. per hr. feedwater heater. Feedwater is pumped by two 10 by 7 by 12-in. duplex pumps.

Coal brought by truck is elevated by a bucket elevator to a storage bunker, whence it is distributed by weigh larry.



Principles and Design of Surge Tanks

PART II. CONTINUATION OF CALCULATION FOR SIMPLE SURGE TANK; ANALYSIS OF ACTION OF TANK WHOSE SIZE WAS FIGURED IN PART I. BY JOHN S. CARPENTER

IN OUR LAST article on this subject, which appeared in the April 15 issue of Power Plant Engineering, the writer referred to certain defects in the method of computation there given. By this time certain readers may have wondered why the method was given at all if known to be defective. Rigidly correct surge tank design is a complicated procedure and, what is more, there are mighty few mathematicians who can handle all the calculus required to take into account all the variables that enter into the problem if it is rigidly considered. Furthermore, some of the differential equations that arise in the development of the necessary equations cannot be integrated with our present knowledge of functions; all solutions, therefore, are approximations in a greater or less degree.

In such a state of affairs, careful engineers will resort to step-by-step numerical computations when there is any doubt that a critical point exists or that the results to be expected will be uncomfortably near a specified condition or limit. Surge tank equations given in textbooks are not properly identified in all cases as to their range of application. If investigated, most of these will be found to cover some comparatively narrow range or field; they are often based on assumptions that are not true in practice; for example, the friction varying as the first power of the velocity instead of as the square, an assumption which leads to appreciable error in quite common cases but is necessary in order to integrate a fundamental equation.

STEP-BY-STEP COMPUTATION REQUIRES PATIENCE BUT IS NOT DIFFICULT

Step-by-step numerical computations above referred to are exceedingly simple, merely requiring patience and care in arranging and following the process. If desired, as many variables as seem justified may be handled in this manner, securing a high degree of accuracy and a complete time history of the process. The great secret of such work is simply to divide the work into many small parts of time, supposing that the various happenings remain substantially constant during those time intervals.

We shall now take our same problem and design the tank for the demanded load condition, all the primary constants of which were given in the first article of this series. In our case, the static head, which is the sum of the effective head, the velocity head and the friction head, amounts to 53.89 ft. and is the water level in the surge tank and forebay or dam when no water is flowing through the pipe line. At zero time, or the instant that the units are supposed to take on this amount of load corresponding to 500 cu. ft. per sec., no water is assumed to be flowing, so that the friction and velocity heads are both zero. As it will be agreed that the water in the pipe line from the forebay down to the turbines cannot be started flowing in time to supply the turbines at the necessary flow rate, it is plain that the turbines will draw on the water in the surge tank immediately. To simplify the problem for the student, we will assume that the water quantity discharged by the turbines does not change from 500 c.f.s. during the whole process. This is not strictly true, for to develop a given amount of power the water quantity must vary inversely as the head, all other factors remaining constant. Having settled on this point, we can easily compute the surplus or deficiency of water flow at any time. It may here be noted to good purpose that the effect of an inadequate surge tank is further to distort the head variations on the dangerous side and not to minimize them.

Tank area being 938 sq. ft., corresponding to 34.6

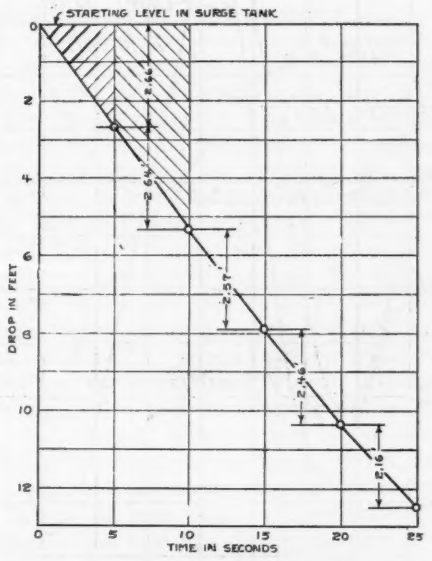


FIG. 9. CURVE SHOWING RATE OF FALL OF WATER LEVEL IN SIMPLE SURGE TANK UNDER CALCULATION

ft. diam., it is plain that a draft of 500 cu. ft. each second will draw the level down 0.533 ft. in each second so drawn. This dropping level constitutes a disturbance of balance and, as the water at the forebay is at a higher level than in the tank, the water in the pipe line will be started flowing toward the region of lower pressure, the difference in head being the accelerating means and the greater the difference the greater the degree of acceleration brought about. Any difference in level in the surge tank and the forebay is transmitted back to the forebay with a velocity, in the case of steel pipe, of between 3800 and 4650 ft. per sec., depending on the pipe construction. It is thus practically instanteous. Dividing our time element into periods or intervals of 5 sec. each, we shall shorten the work considerably. For quick preliminary work in investigating a proposed tank, the time element can be taken as 10 or 20 sec. without serious errors creeping in.

Referring now to Fig. 9, we show on large scale the falling level in the surge tank In the first 5 sec. the

water demand will be 2500 cu. ft., as the pipe line furnishes no water so far. This draws 2.66 ft. of head from the tank. The total acceleration so far will be the area of the small triangle, which is 6.65 square units. The corresponding velocity at the end of the 5th second will therefore be: (6.65 × 32.2) ÷ 5000 or 0.0429 ft. per sec. which is very slow indeed. From the end of the 5th second to the 10th, we have a much larger triangle. The water deficiency now is 5.000 ft. vel. — 0.0429 ft., or 4.957 ft., and the draft of water this

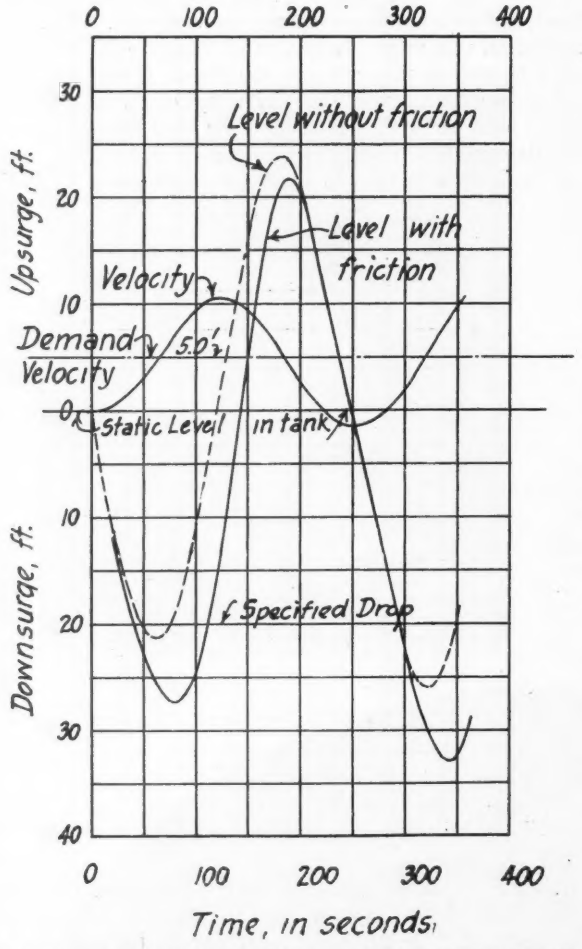


FIG. 10. TIME HISTORY, SHOWING ACTION IN THE SURGE TANK UNDER CALCULATION; 500 C.F.S. DEMAND

time will be 4.957 × 5 sec. ÷ 938 sq. ft., or 2.64 ft. drop. The last previous drop was 2.66 ft., to which we add half of the present drop, making a total of 3.98 ft., giving an increased area of 19.90 sq. units, which, added to the previous area of 6.65, gives a new total of 26.56 units and a corresponding new velocity of flow at the end of the 10th second of 26.56 × 32.2 ÷ 5000, or 0.171 ft. per sec. Now we can begin to use constants to shorten our work and we find that 26.56 ÷ 155.3 will give us the same result. In the same way, we proceed with the interval from the end of the 10th second to the end of the 15th second, and now find the deficiency of flow to be 5.000 — 0.171, or 4.829 ft. velocity, which, to use a new constant for our case, gives a further head drop of 4.829 × 0.533, or 2.57 ft. The two last drops total 5.30 ft., which, increased by half of 2.57, gives a new total acceleration head of 6.58 and this value multiplied by 5 sec. gives the increase of 32.90 sq. units. This last previous total area was 26.56 and this increased by 32.90 makes a new total of 59.46, which divided by the constant 155.3, gives a new velocity of 0.383 ft. sec. Thus we go on, until at the 20th second, the pipe friction begins to be appreciable. Knowing the pipe friction head to be 3.5 ft. for the normal velocity of 5.0 ft. per sec., we can easily find it at any other velocity with the constant 0.14 times the velocity squared. In some cases, it might be well to take into account the velocity head, which can be done by adding the velocity head to the friction head, considering the total as all friction, then finding a new constant. In our case, the total would be 3.89 ft., therefore the constant is $3.89/v^2$, or 0.155; however, here the error is small.

Computations Should Be Tabulated for Convenience

Much is to be gained by arranging the computations in a neat and business-like form such as in the table which shortly follows. The results can be kept in mind much better and errors tend to show up more obviously by their great differences. The column headings are numbered in brackets and references made to such numbers in various other columns. Only sections of the original table are here given, such as for critical points, so the reader may see how the turning points of the curves are handled, to save space. A much clearer idea of what is going on can be gained if the curves are plotted while the computations are being made. This tends to make errors more obvious.

Referring to the curve, Fig. 10, we have a good picture of the happenings within the tank and the pipe line. The dotted line shows the surging water level as it would appear if there were no pipe line friction to be considered. The amount of pipe friction is always subtractive and pulls the tank level down from the theoretical level according to the momentary value of such friction. Thus it will be seen that friction of the water in the pipe tends to damp the upward surges and to increase the downward surges. The velocity curve shows how the velocity varies and around the 225th second the curve of velocity has reversed and water is actually flowing from the tank back to the forebay or dam.

Results Show Inherent Defects of Simple Tank

The problem we selected for working out in detail shows several inherent defects of the simple surge tank. First of all, it will be noted that the first downsurge exceeds the 20-ft. value specified in our problem. Discouraging evidence of this is the fact that the next upsurge is nearly as great as the downsurge was. But the most glaring and unpardonable thing is that the second downsurge is greater than the first, therefore succeeding waves cannot be better in this regard. The ultimate effect of the increasing surge is that the tank will finally be drained and the plant will lose its load. No satisfactory kind of regulation is to be expected from a tank of such proportions and we wonder what kind of governing is realized in plants having a still smaller ratio of surge tank area to pipe area than we

have here, remembering that surge tanks having the same diameter as the pipe itself have often been built.

To make the matter still worse, if we had considered the correction in water quantity due to the reduced heads while the tank level was below normal, the down surges would be still greater in extent. We described in our last article the desirable feature of having the tank "dead beat." This is anything but dead beat. The ideal case is that in which the pipe line velocity is quickly accelerated to the demanded value and then stays there. In our present case, we note that the velocity increases slowly, gradually attains the demanded value and then widely overshoots the mark by finally reaching a value more than twice the desired amount.

What is to be done? Well, we can increase the size of the surge tank and that is about all we can do as long as we have decided to stick to the alleged simple type. Our criticisms have been harsh but they are certainly true and these faults are all characteristic and inherent in the simple tank. Making the tank of greater diameter and area will certainly reduce the amounts of the surges both up and down but the tank when so increased in size will be relatively slower in getting into action.

TABLE SHOWING METHOD OF TABULATING COMPUTATIONS FOR SIMPLE SURGE TANK

Time Int'v'l	(1) Veloc. excess or deficit	(2) $\Delta Y = \frac{533 \times (1)}{}$	(3) Previous value of Y	(4) Area increase	(5) previous Area total	(6) New Area total	(7) Velocity for next Interval (6)÷1553,	(8) Y plus Y	(9) Pipe Friction $.14\ v^2$
0-5	5.000	2.660	0	6.66	0	6.66	.0429	2.66	0
5-10	4.957	2.640	2.66	19.90	6.66	26.56	.171	5.30	0
10-15	4.829	2.570	5.30	32.90	26.56	59.46	.383	7.87	.021
15-20	4.617	2.460	7.87	45.35	59.46	104.81	.675	10.33	.064
20-25	4.325	2.142	10.33	57.10	104.81	161.91	1.041	12.49	.154
25-30	3.959	2.110	12.49	67.76	161.91	229.67	1.480	14.60	.310
50-55	1.220	.651	20.39	103.60	587.32	690.9	4.450	21.04	2.770
55-60	.550	.293	21.04	106.00	690.9	796.9	5.130	21.33	3.680
60-65	.130	.069	21.33	106.50	796.9	903.4	5.810	21.26	4.730
65-70	.810	.432	21.26	105.2	903.4	1008.6	6.480	20.83	5.880
70-75	1.480	.790	20.83	102.3	1008.6	1110.9	7.150	20.04	7.160
75-80	2.150	1.146	20.04	97.5	1110.9	1208.4	7.780	18.90	8.460
80-85	2.780	1.480	18.90	90.8	1208.4	1299.2	8.360	17.42	9.780
85-90	3.360	1.792	17.42	82.7	1299.2	1381.9	8.900	15.62	11.100
90-95	3.900	2.080	15.62	72.9	1381.9	1454.8	9.380	13.55	12.300
110-115	5.32	2.840	5.94	22.6	1602.9	1625.5	10.47	3.11	15.380
115-120	5.47	2.920	3.11	8.2	1625.5	1633.7	10.52	.185	15.500
120-125	5.52	2.950	.185	6.5	1633.7	1627.3	10.48	2.765	15.400
125-130	5.48	2.920	2.765	21.1	1627.3	1606.2	10.34	5.69	15.000
130-135	5.34	2.850	5.69	35.5	1606.2	1570.7	10.12	8.54	14.350
135-140	5.12	2.730	8.54	49.5	1570.7	1521.2	9.80	11.26	13.430

Satisfactory solution of the problem will be to introduce a large frictional dampening element into the tank. Then, to use the words of R. D. Johnson, we separate the accelerating and retarding features from the mere storage feature. This solution can be brought about by using a restricted orifice in the simple tank, also by using the differential method patented by Mr. Johnson. The writer is not financially interested in either of these nor in any other type of surge tank, therefore he is ready to criticize both types. One criticism can be made of any "throttling" type of tank: the pressure changes are sudden and of practically the full surge value either up or down, though this can be somewhat modified by careful design; good judgment, based as usual on study and experience, also enters into the matter. In our closing article on this subject we shall consider corrections to our first method of design and shall discuss means to overcome some of the undesirable features of the simple tank, the use of which leads to complications.

(To be concluded)

Delray Power House No. 3 Will Install Stokers

FOR THE FIRST six boiler units of the new plant, now in course of construction, which is to be known as Delray Power House No. 3, The Detroit Edison Co. has just decided to install underfeed stokers. Inasmuch as this company's Trenton Channel plant, which immediately preceded this in construction, is equipped for pulverized fuel burning, the choice of stokers for Delray No. 3 might be misinterpreted as indicating that in the opinion of the company's engineers the stoker method of firing had inherent advantages over the pulverized fuel method. Any such inference would be misleading in the extreme, according to J. W. Parker, chief engineer of the company, in an article in the May issue of the Synchroscope.

It is pertinent to explain that until Trenton Channel was built, it had been The Detroit Edison Co.'s long established practice in all of its power plants, Delray, Connors Creek and most recently at Marysville, to employ an underfeed type of stoker well suited to the character of the best coal ordinarily available: a comparatively low-fusing, extremely high volatile, bituminous coal from West Virginia and Eastern Kentucky. Long experience with stokers had developed the company's stoker practice to a satisfactorily high standard at the time the Trenton Channel plant was designed. Use of pulverized fuel at Trenton was, therefore, a new departure in the company's practice. The factor which conclusively determined that departure was the belief, later amply borne out by the result, that with pulverized fuel the plant would very easily adapt itself to minor variations in character of coal without impairment of capacity and with a minimum impairment of efficiency.

Trenton Channel, with the last of its complement of six 50,000-kw. turbines now being erected, has justified the decision made at the time its design was fixed.

At Delray the new plant will be handled by the same organization that has superintendence of the two older power houses, Numbers 1 and 2. The management of stokers for high efficiency will be no novelty for that group of men. Estimates of performance and of required investment for the two types of plant (stoker and pulverized fuel) indicate total costs for the Delray location so nearly alike as to suggest the question whether or not the difference is of the same order as the possible errors of estimate. The final decision to install stokers in the first section of plant was determined by a consideration ordinarily too insignificant to become a controlling factor. Up to the present time no permanently satisfactory way has been found for disposing of the fine ash produced by pulverized fuel furnaces, after it has been caught. At Trenton Channel there are still marshes to be filled in but there are no longer any such hollows near Delray. Conversely, the sale of stoker cinders from the Delray plant in a local market, which it has never been possible to satisfy, will earn a credit of something more than 6½ cents per ton of coal burned.

Design of the new Delray boiler furnaces can be easily adapted to pulverized fuel and the plant would accommodate the necessary equipment but until this particular commercial problem of ash dust disposal is solved, The Detroit Edison Co. prefers and will continue the use of stokers at the Delray plants.

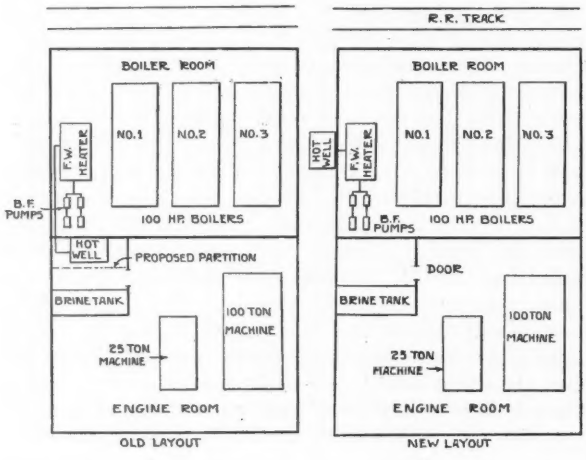
Refrigeration Troubles in a Packing House

By C. E. Anderson

ON A RECENT inspection trip to one of our Southern packing houses, a brother engineer came and visited me from a neighboring city. Among other things, he requested that I visit his plant before I left this territory, as he was in trouble—could not keep proper temperatures in certain parts of his plant—and wanted some advice as to what might be the trouble.

Several days afterward I went to see his plant and was glad that I did. I saw something that I had never seen before—a B.t.u. battle between a 25-t. ammonia compressor and the hot well of a barometric condenser.

The engineer showed me all about the plant and he had a neat, clean and well running plant as far as I could see. He next showed me into a partitioned, insulated room in one corner of the plant. Here is where all of his troubles were located.



NEW AND OLD LAYOUT OF THE EQUIPMENT IN THE BOILER AND ENGINE ROOM

On entering this room, I nearly lost my breath and skin at the same time. The temperature of this room must have been in the neighborhood of 140 to 150 deg. The electric lights being out of commission here, the engineer went after a lantern so we could see. On his return, we entered the room again and this is what we found.

On one side of the room was a large, insulated wooden vat, filled with brine and ammonia piping for cooling the brine, and on the other side of the room was located an iron tank, which happened to be the hot well of the barometric condenser. Readers can imagine the condition of this room.

Informing me that he had recently taken charge of this plant and that he was a locomotive engineer who had to leave the road on account of poor eyesight, the engineer said among other things that he was not familiar with all the phases of refrigeration, but he knew there was something radically wrong with this end of the plant, although he did not know exactly how to overcome the trouble.

This brine tank was used for cooling calcium brine, which in turn cooled a lard roll and a small storage room, which held the day's run of lard and other commodities that had to be kept cool. In shutting down this part of the plant, he informed me that the brine in the tank rapidly rose in temperature to anywhere from 90 to 120 deg. F. overnight. This made it necessary to start cooling brine about 3 a. m., in order to have it down to zero by 7 a. m. A 25-t. compressor was connected directly on the direct expansion piping of this tank to do this work. Since it was difficult to hold this brine at zero during operation of the roll, it became necessary to shut the rolls down several time a day in order to get the temperature of the brine down to zero again. This meant a severe loss in capacity and a source of annoyance to all concerned.

On shutting down at night it was necessary to pump a slight vacuum on the ammonia piping in this brine tank, otherwise the pressure rose to around 220 lb. in these coils, causing leaks and loss of ammonia. This, of course, meant extra hours of operation of the compressor to do this work of pumping out.

Here was an unusual opportunity to make a big saving in the operating expense of this plant by means of a few changes and at a comparatively small cost.

We first considered building an insulated partition between the two tanks and directly through the center of the room, as illustrated in the sketch, but upon more deliberate thought and examination of the layout of the plant, we decided that it would be far better to move the hotwell to some other part of the plant.

The new location is noted in the sketch.

After mapping out what we wanted to do, we submitted the proposition to the management and they were eager to co-operate with us in every way to bring about better operating conditions and higher efficiency of the plant.

So the following Sunday we started in bright and early to make the changes we had mapped out, as shown in the sketch. We first removed the hot well from the brine tank room, placed it outside the boiler room near the feedwater heater and changed the piping of the barometric condenser to fit this location of the hot well. We also changed the piping to feedwater heater and boiler feed pumps.

Sketch No. 1 shows old layout of plant and sketch No. 2 shows the new layout with all the changes. The changes we made worked better than we anticipated. The brine rose only 12 to 15 deg. during the night and starting the compressor at 6 a. m. gave us ample time to get the brine to zero before starting the lard rolls at 7 a. m., and we experienced no trouble during the day's run in holding it at this temperature—in fact, we had to slow the compressor down somewhat, as the brine was getting so cold there was danger of freezing it. The following Sunday we insulated the brine vat with 6 in. of cork all around, which made conditions nearly ideal and greatly pleased everyone concerned.

City of Eugene, Oregon, C. A. McClain, City Water Superintendent, has asked for bids for the construction of a hydro electric plant of 210,000 hp. capacity in connection with the Leaburg hydroelectric power development. Stevens & Koon, Spalding Bldg., Portland, Ore., are consulting engineers.

Varied Program Feature of Power Conference

WE WISH to call your attention to the following corrections applying to your abstracts of papers presented before the Midwest Power Conference appearing in your March 1 issue.

On page 321, the article by G. A. Orrok, "Operating Experiences with High Pressure and High Temperature Steam," reads, "There are two Benson boilers at Siemensstadt, one for 200 lb., and the newer and larger boiler at the cable works operating at about 2800 lb." However, the steam generation in both boilers takes place at the critical pressure of about 3200 lb., with this difference, that the steam is throttled to 100 at., or 1420 lb. per sq. in., before entering the turbine in the old experimental plant, and to 180 at., or 2560 lb. per sq. in. in the Gartenfeld cable works.

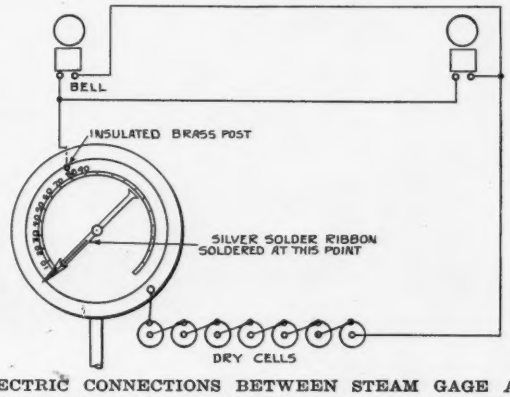
On page 323, the article by Thos. E. Murray, "Trend and Development in Steam Generation" reads, referring to the same two boilers, " . . . one of these boilers having a capacity of 250,000 lb. of steam per hr." While the boiler erected in the cable works at Gartenfeld delivers normally about 55,000 lb. of steam per hour and a maximum of 66,000 lb. per hr., the experimental plant in the power plant of the Siemens-Schuckertwerke is designed only for about 22,000 lb. per hr.

Berlin, Germany. SIEMENS-SCHUCKERTWERKE, A. G.

High-Pressure Alarm Reduces Fuel Consumption

SOME TIME ago, I was confronted with a complicated situation that I helped to remedy by means of the gage and alarm bell described here. At this plant, shavings and wood refuse alone were used as fuel. At the time of this trouble, business was dull and the amount of refuse limited. The plant was operating only four days a week. To keep sufficient steam for the pumps, fan engines and dry kilns, every day and night meant rigid economy. Our firemen were like most firemen, in that they were pleased at the prospect of getting off on Saturdays and Sundays whenever possible. In order to accomplish this, they would try to keep from storing shavings. In other words, instead of feeding the shavings in small amounts and often, they would stuff the combustion chamber as full as possible, open up the damper and fire-doors, letting the steam climb up to pop-off pressure. The night men would work along the same lines, even throttling down the valve leading to the steam pressure indicating recorder.

After instructing the firemen to discontinue these wasteful practices, I rigged up a steam gage to the steam main in the engine room. To the hand of this gage I soldered a thin strip of silver solder ribbon, 4 in. long. Then on the edge of the gage face I set an insulated brass pin opposite the figure representing 80 lb. steam pressure, as shown in the illustration. When the gage hand would reach 80 lb. the silver ribbon would lightly touch the pin and start the bells ringing. One bell was in the engine room and the other in the boiler room.



ELECTRIC CONNECTIONS BETWEEN STEAM GAGE AND ALARMS THAT ATTRACT ATTENTION TO HIGH PRESSURE IN BOILER AND REDUCE WASTE OF FUEL

The silver solder strip was so thin and small that its presence on the gage hand did not hinder the hand in its movements.

Firemen were instructed to cease firing as soon as the bell started ringing. When business conditions improved, the refuse supply increased and the necessity for such rigid economy vanished with it.

Moline, Ill. ROBERT ALTHAUS.

Shift Vs. Watch Engineers

IN PRACTICALLY every stationary power plant outside of the coal mining industry, the term "watch" is used to designate certain hours of labor of an operating engineer. In the coal mining industry the same period of duty is called a "shift." In my opinion, the term "watch" as applied to stationary plants is incorrect.

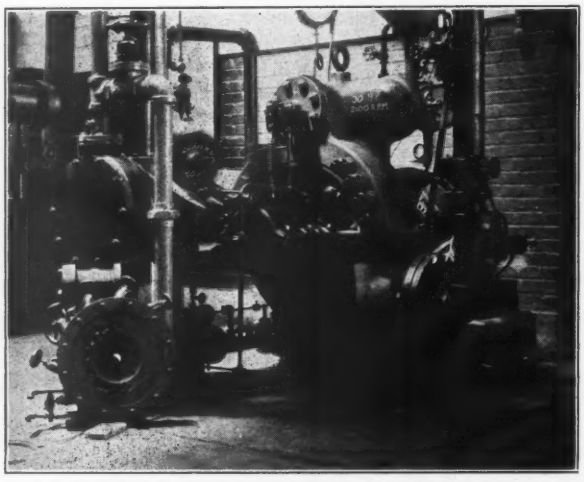
This term originated in the marine service and is correct in that sense as an engineer on watch seldom, if ever, leaves his post of duty during his period of watch, while, in stationary plants, the engineer attends the engine when he has no oiler; he is not merely waiting in the engine room for the jingle of a bell but is usually all around the plant from oiling the engines to cutting in a boiler and perhaps packing a pump in some distant part of the plant. At such times, he leaves the engines to run without any attention. I do not have reference, of course, to the large super-power plants nor to the plants where the engineers are required by law to remain in the engine room while on duty.

Referring to Webster's dictionary, we find the word "shift" defined as "turning from one thing to another". This better fits the power plants the writer has in mind.

Louisville, Ky. FRED E. BOND.

Influence of Speed on Size

MANY a man has guessed the output of a piece of machinery incorrectly through failure to take into consideration the speed of the machine as well as its bulk or frame size. The effect of speed on size and output is strikingly shown by the accompanying photograph, which shows two De Laval steam turbines, each rated



STEAM TURBINES OF SAME CAPACITY DIFFER GREATLY IN SIZE DUE TO DIVERSITY IN SPEEDS

at 30 hp. output, in the mechanical laboratory of the Rice Institute.

One of the turbines, a modern 2100-r.p.m. machine, is shown completely assembled. The rotor of the other is seen lying on top of the condenser, while the casing belonging to it stands on the floor in the foreground, with the outlet of its nozzles exposed. This disassembled machine is one of the old high speed models with flexible shafts, designed for generator drive through herringbone reduction gears. In this case, the generator ran at 2000 r.p.m., with a reduction of 10 to 1 in the gears, giving a turbine speed of 20,000 r.p.m.

The effect of this great difference in rotary speed is shown strikingly in two ways: in the bulk of the two machines (as shown in the photograph) and in the diameter of the turbine shafts. In the case of the high speed machine, the shaft connecting turbine disk and pinion gear is ⅜ in. in diameter; but in the low speed machine the shaft becomes 2½ in. in diameter.

For the high speed turbine, the disk diameter measured over the blade tips is about 9⅝ in., giving a rim speed of 840 ft. per sec. or 573 mi. per hr. For the low speed turbine, the maximum disk diameter is 29⅛ in., giving a rim speed of 265 ft. per sec. or 182 mi. per hr.

Houston, Texas. J. H. POUND.

Examinations for Operating Engineers

REFERRING to Fred E. Bond's remarks on the above subject, published on page 428 of the April 1 issue, I would suggest that he consider all sides of the question. If a certain set of questions, say 50 sensible and important ones were established, how long would it be before every "jackleg" in the country, who wanted a license, would have a copy of the questions and the correct answers memorized in parrotlike form after having been coached by some licensed friend.

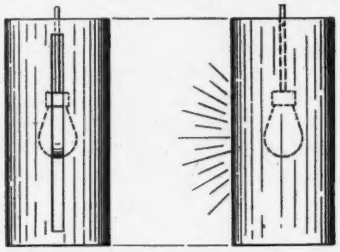
There has been altogether too much of that kind of engineering education already. This is the principal cause for the well known deplorable status of operating engineers.

Hagerstown, Md. H. P. STEPHENSON.

Editor's Comment: Not standardization of questions, which would without doubt lead to the above mentioned condition, but rather clarification of type of questions, as stated on page 324 of the March 1 issue, is what is desired. Elimination of catch questions, of questions with insufficient data, of foolish, vague and irrelevant questions is what is needed.

Confined Lighting as a Safety Kink

IN A BOILER room recently, I saw an excellent method of lighting a boiler gage glass. A tin tube, open at the top, with a slit ⅜ in. wide nearly the full length of the tube, was suspended at one side of the water



SLIT IN TIN TUBE COVERING LAMP DIRECTS LIGHT ON GAGE GLASS

glass, the slit facing the glass. A 15-w. lamp hung inside the tube, as shown in the illustration, thus causing strong light to be thrown onto the glass. As no other light was present, the water height in the glass was clearly visible from any position.

In my opinion, this scheme is better than many of the schemes used for this purpose. A great many boilers have an open light hanging at the glass; this shows up the water level to some extent but often it is of little use unless the observer stands in some particular spot. If a boiler has been supplied with a drop light near the glass, a piece of tin tube may be easily fitted to it as indicated. It will cost only a few cents.

West Vancouver, B. C., Canada. JAMES THORN.

They Burn 'Em All Night

"WHAT I CAN'T understand," remarks every stranger who visits the little town of Tullahoma, Tennessee, "is why everybody in town leaves his front porch light on all night long! I can see why a few could afford to be so extravagant, but I notice all over town, little houses and big houses, new houses and old houses, all have their front porch lights turned on at dark and left burning all night. It is pretty, but how can they afford—"

This rather unique custom is not an extravagance of the citizens of Tullahoma, Tennessee. Rather is it co-

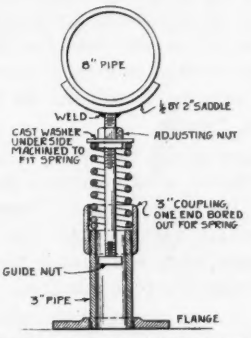
operative economy. For, many years ago, this custom was established in this way: The porch light of every home is put on the city's meter and is given free with the understanding that the patron will burn it all night long. Thus, at no expense to the citizens, the streets are well lighted all over the town. The rows of porch lights effectively aid the street lights; the town is given a wide-awake, hospitable appearance, and each citizen has the protection and pleasure of a light burning on his porch all night.

Incidentally, there is practically no thievery in this little town of the all-night-burning porch lights.

Tullahoma, Tenn. I. P. RICHARDSON.

Spring Support for Pipe Line

I AM enclosing a sketch of a spring support which I recently designed in a hurry for carrying the atmospheric relief line to a 1000-kw. bleeder turbine.



SPRING AND FITTINGS FORM FLEXIBLE PIPE STAND

It is crude but works well. It was made in 45 min. from old pipe and fittings.

Lincoln, N. H. A. P. NUTTER.

Influence of Instruments Upon Performance

IT IS NOT the installation of instruments in a power plant that cuts the cost of operation but the knowledge derived from the use of these instruments.

If instruments are not properly checked from time to time and properly maintained, they are worse than useless because they are misleading. I am conversant with a plant that produced more goods and at the same time cut its fuel cost over $30,000 in one year.

Did the instruments do this? No, but the tales they told furnished the man in charge with more ammunition than a keg of T.N.T. and with that backing he was able to produce results.

New York City. JOE BROWN.

Silver Solder Withstands Severe Starting Conditions

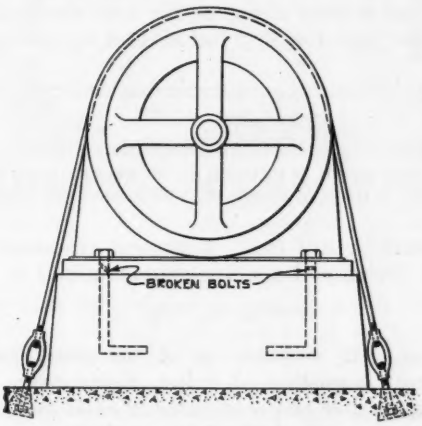
WHILE THE ROTOR element was out of a machine some of the rotor bars were found to have loosened up, due to the strain imposed by the severe starting conditions. These bars were silver soldered before the rotor was replaced. It is practically useless to use ordinary solder on rotors as any severe overload will cause the rotor bars to heat and throw it out. It is comparatively easy to silver solder rotor bars if the copper section is large enough to prevent melting the copper under the oxy-acetylene flame. There is one point to observe and that is, to have the copper absolutely clean before soldering. In this case the cleaning was accomplished by suspending the rotor by means of a crane over a small tank of a chemical cleaning compound which was kept boiling by means of a gas heater. The rotor was revolved in this cleaner and all dirt, grease and foreign matter was quickly removed, after which the rotor was silver soldered.

Woodward, Okla. HARRY J. ACHEE.

Tie Rods Anchor Motor Securely

AN EMERGENCY repair which gave great satisfaction was made, as shown in sketch, to a 30-hp., 1800-r.p.m. motor driving a stoker fan in our plant. Three of the four foundation bolts were broken off, which meant a shutdown if the other one broke. Not having time to put in new foundation bolts, as we would have had to take the motor up and shut down the plant, we made the repair without losing any time at all.

Four holes were drilled in the concrete floor at the base of the foundation and ¾ by 6-in. machine bolts



TIE RODS, AS REPAIR EXPEDIENCY, REPLACE BROKEN FOUNDATION BOLTS AS FASTENING FOR MOTOR

were anchored in with lead. Turn-buckles were used on each bolt and a ¾-in. rod run around each end of the frame of the motor and tightened up. This work was accomplished in about an hour's time.

Since this repair, which was made four months ago, proved to be so good, we have never cut up the foundation to put in new bolts.

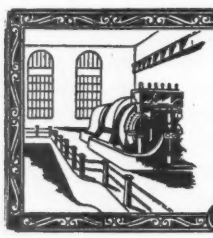
Knoxville, Tenn. S. A. MAPLES.

Use of Vise in Pulling Keys

IN ATTEMPTING to remove a rocker arm which was keyed to a duplex pump shaft, the key was found to have broken off at the shoulder.

One of the men said, "Watch me take out that key." He removed a vise from the work bench, brought it over and gripped the remains of the key tightly in the jaws of the vise, then driving a couple of cold chisels as wedges between the rocker arm and the jaws of the vise, the key was pulled out far enough to loosen it. Thus a possibly difficult job of drilling and cutting was avoided and the key removed in a few minutes.

Hollyburn, British Columbia. JAMES E. NOBLE.



QUESTIONS AND ANSWERS

Boiler Efficiency and Water Hammer

WILL YOU KINDLY answer the following questions?

1. What is the difference between the "thermal efficiency of a boiler and furnace" and the "evaporative efficiency of a boiler"?

2. What causes coal to clinker in the fire?

3. Explain what causes water hammer and what takes place during this condition. J. T.

A. The combined efficiency of the boiler, furnace, grate, etc., which includes all of the elements that contribute to the heat exchange from the fuel to the steam as drawn off from the boiler, is the percentage of the heating value of the dry fuel utilized in heating the water and making steam, or the heat absorbed by the water per pound of dry fuel divided by calorific value

WATER HAMMER IS CAUSED BY FORMATION OF POCKETS IN WHICH WAVES OF CONDENSATION MEET

per pound of dry fuel. A general expression of this overall efficiency of a steam generating unit is:

$$E = W\ (H - q) \div F$$

Where: E = efficiency of the steam generating equipment consisting of boiler, superheater, furnace, grate, air heater and economizer or of as many of these appliances as are included in the equipment.

W = weight of feedwater evaporated into steam, at the observed pressure and quality, in pounds per pound of dry fuel.

H = heat content of steam at the observed pressure and quality, in B.t.u. per pound above 32 deg. F.

q = heat content of the feedwater as fed into the boiler in B.t.u. per pound above 32 deg. F. The efficiency is frequently expressed as "with or without economizer." The former is obtained by taking q as the heat content of the water entering the boiler and the latter as that of the water entering the economizer. For all practical purposes, q may be taken as t — 32 in which t is the temperature of the feedwater in deg. F.

F = heat value of dry fuel.

Evaporative efficiency of a boiler is the percentage of the total heat generated by the combustion of the fuel in the furnace that is utilized in heating the water and raising steam.

This latter has nothing to do with losses in the furnace and grate, therefore it does not account for percentage of ash in fuel, loss of fuel through grates and similar losses.

2. Ash that fuses at comparatively low temperature is the principal cause of clinker formation.

3. Water hammer in steam heating pipes is caused by water, resulting from condensation, which forms in waves with pockets of steam between them, as shown in the drawing. The air around the pipe being cooler than the steam causes the steam to condense, thereby creating a partial vacuum which forces the two "waves" of water together with such a slap that the pipe vibrates. In a heating system, there is little likelihood of water hammer if the pipes are properly drained. Maintenance of sufficient drop in all horizontal lines and installation of traps at all low points will establish proper drainage. Also, if the pipe is large enough to permit the steam to travel at a low velocity, it will not be likely to pick up water and form "waves."

Water hammer is also caused by foaming and priming in a boiler when it is so connected that slugs of water are passed into the steam pipes. These slugs of water acquire considerable velocity and due to their inertia hit any obstruction, such as a turn in the pipe or a valve, with such force that the pipe vibrates.

Deterioration of Coal in Storage

CONSIDERABLE difference of opinion seems to exist regarding the deterioration of coal while in storage. I would like to hear the experiences of some of the other readers of the magazine regarding this matter, particularly in regard to summer and winter, open storage for a period from six months to a year. H. E. M.

Calculation of Boiler Drum Strength

HOW DO YOU calculate the strengths of the various sections of a cross drum for a water-tube type boiler? W. E. L.

A. There are three forms of connection used at the tube ligament of drums. One of these, in which the tube ligament is not at a butt strapped seam but has one reinforcement to offset the weakening due to the tube holes, is shown at Fig. 1. The strengths of the various sections as indicated in the figure are found by the following corresponding formulas.

A: $P \times t \times T$
B: $(P - H)\ (t + t^1)\ T$
C: $(P - H)\ t \times T + (n \times S_s)$
D: $(P - d)\ t \times T$
E: $(P - 2d)\ t \times T + (1 \times S_s)$

Where P = long pitch of rivets also pitch of tube holes.
H = diameter of tube holes, in inches.
d = diameter of rivet holes, in inches.
t = thickness of drum plate, in inches.
t′ = thickness of strap plate, in inches.
T = tensile strength of metal in lb. per sq. in.

N = number of rivets.
S_s = shearing strength in single shear, lb. per sq. in.
S_d = shearing strength in double shear, lb. per sq. in.

A represents strength of unit section of solid plate.

B represents strength of unit section at tube ligament.

C represents strength of unit section of shell plate tube ligament plus rivets in shear.

D represents net section of shell plate at outer pitch (longest pitch).

E represents strength of net section at short pitch plus rivet in shear in long pitch.

Dividing B or C, etc., by A gives the percentage strength or efficiency of section = e and $(t \times T \times e) \div (r \times f)$ = safe working pressure.
where r = radius of drum in inches,
and f = factor of safety.

In the second form, as shown in Fig. 2, the tube ligament is a butt strapped seam in which there may be one or two rows of tubes and where two straps are used. In this case the section along the line of the tube hole seam would have no strength as the ends are merely butted in contact. Then, following the same general designations, the strengths will be:

A: $P \times t \times T$
B: $(P - H)\ (t' + t'')\ T$
C: $(N \times S_d) + (N \times S_s)$
D: $(P - d)\ t \times T$
E: $(P - 2d) \times t \times T + (1 \times S_s)$
F: $(P - 2d) \times t \times T + (1 \times S_s) + (2 \times S_d)$

Here C represents the strength of all rivets in shear and t'' represents the thickness of the outer strap plate in inches.

The percentage efficiency of section and safe working pressure are found as before.

In the third form, as shown in Fig. 3, the shell is butt strapped as in Fig. 2, but there are two rows of tube holes and the seam lies between these rows. The seam is tack riveted in this case, with rivets of same diameter as those used for the straps. These rivets, however, act merely as pins to guide the plate into position.

In this case, the strengths of the sections are found as follows:

A: $P \times t \times T$
B: $(P - d)\ (t' + t'')\ T$
C: $(P - H)\ (t + t' + t'')\ T$
D: $(N \times S_d) + (N \times S_s)$
E: $(P - d)\ t \times T$
F: $(P - 2d)\ t \times T + (1 \times S_s)$
G: $(P - 2d)\ t \times T + (1 \times S_s) + (4 \times S_d)$

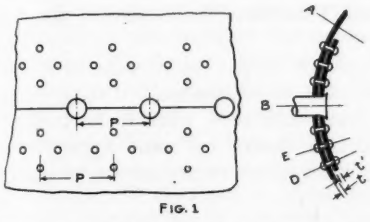


FIG. 1

FIG. 1. TUBE LIGAMENT WHICH IS NOT SPLIT BUT HAS REINFORCEMENT STRAP TO MAKE UP STRENGTH LOST BY HOLES

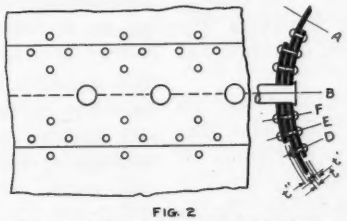


FIG. 2

FIG. 2. TUBE LIGAMENT WHICH IS SPLIT THROUGH THE TUBE HOLES AND HAS TWO STRAPS

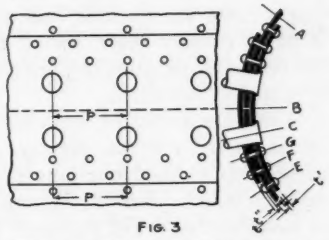


FIG. 3

FIG. 3. TUBE LIGAMENT IN WHICH THERE ARE TWO ROWS OF TUBE HOLES WHICH STRADDLE THE SPLIT IN THE PLATE

Fusible Plugs

WILL a fusible plug blow out if covered with water? If so, what causes this to happen?

Is it possible that when the filling melts out on the outside so much as to weaken it, it cannot stand the pressure and blows out? I have had this happen to one of my firemen twice in six weeks. He steadfastly maintains that he had plenty of water in the glass at the time and when I returned 10 min. later, he had three gages of water. The glass was working correctly, as I tested it, and I tried the cocks on the water column. He had three gages of water when I left a half hour before and the boiler was carrying a load of only 2000 lb. per hr. during that time.

This happened on our 200-hp. horizontal return tubular boiler which, until two months ago, had been hand fired; we now have a semi-mechanical stoker attached. We run 24 hr. per day with peak loads; the boiler developing from 50 to 220 hp. per hr. We use Massachusetts standard plugs of the outside type. We have used plugs before which have been melted out halfway or more on the outside; I took out one which had only ½ in. of filling left in it. The filling in this case had moved out ⅛ in. from the inside. B. S. K.

A. Fusible plugs may blow out under extreme cases even when covered with water. Frequently, also, there is a partial melting of the filling on the outside of the plug, reducing its resistance to pressure. Besides this melting out with its consequent effect of loosening and moving the filling there is another effect due to aging of the plug that tends to harden the filling and cause it to become less dependable. It is, therefore, recommended, in the A. S. M. E. code, that the plug or its filling should be renewed once a year.

Fusible plugs should be filled with tin whose melting point is between 400 and 500 deg. F. The least diameter of fusible metal should be not less than ½ in., except for maximum allowable working pressures of over 175 lb. per sq. in. In order to be at all reliable, the tin used should be as pure as possible. Banca tin, which has the highest reputation of any, is most desirable for this purpose. Even the temperature at which it is poured in the plug may affect its reliability. The tin should be poured at a temperature as near to its melting point as possible.

EDITORIAL COMMENT

Does the Public Really Want Smoke Eliminated?

That the general public is not yet ready to eliminate the costly smoke pall that hangs over many of our cities is apparent to any careful observer. The average citizen does not actually believe that it is he and his fellows, rather than the steam engineering profession, that are responsible for the bulk of this smoke trouble. Furthermore, the average citizen does not want to believe this and does not want to be reminded of it. He prefers to establish a municipal department of smoke inspection, controlled by and for politicians and to pass the buck to this department. The department is usually made up of reputable engineers who are rendered practically powerless by lack of funds and by political influence.

Data are available, however, to prove that domestic smoke is by far the greater part of this cloud that dirties our clothes, our homes, our lungs and shuts off an appreciable part of the sunlight in winter, when it is most needed. Yet furnaces for domestic use can be and are being designed to burn any desired fuel without smoke. Furthermore, experience of a few cities has demonstrated that domestic smoke can be almost entirely eliminated.

This is done only when the inhabitants of a city, acting as a group, agree to do what is necessary. "Necessary" may mean installation of new heating boilers or furnaces, changing of fuel, use of district heating plants and so on. And it costs money. And it cannot be accomplished by discussions among engineers, who are already operating their own plants smokelessly in the interests of economy. Yet at how many meetings representative of the non-technical citizenry of a given city do we hear discussions of smoke prevention?

Viewed in this light, there would seem to be two principal courses open to those interested in eliminating smoke. These courses are: (1) enactment of legislation, possibly national in scope, covering production of smoke, with provision for an adequate enforcement organization; (2) inauguration of a campaign of education.

Despite the fact that engineers may ridicule the first suggestion, they must not forget that the majority of the inhabitants of this country are perfectly willing to turn over to governmental control many other factors just as closely connected with their personal activities as the heating of their homes. One waggish engineer has suggested that if burning of bituminous coal were made illegal, people would bootleg large quantities of it. Then, in order to avoid detection, they would be forced to use equipment and methods necessary to burn it smokelessly.

If one believes that it is impossible to abolish smoke by legislation, then education of the general public remains the only feasible course. Those who have coal to sell are concerned at present about the competition of the oil burner and the manufactured gas heater. Would it be out of place for them to inaugurate a campaign to educate the public in the ways and equipment now available to avoid making smoke? Let them stop talking to the householder about economy. He burns coal not for economy but for comfort. If the coal producers could show him how to secure this comfort by burning coal without making smoke, they would have little to fear from competition of other fuels. Moreover, if they could show him how to burn the lower grades of coal successfully, they would increase their market for all grades.

At all events, if enough people really want to eliminate smoke in a given time, engineers can tell them right now how to do it. But, until they want to be told or are imbued with such a desire by some agency, no amount of technical analysis or protestations of waste will avail.

Survey District for Economies in Services

Taking advantage of existing conditions may often result in economies little appreciated until analyses and calculations have been made. Independence has been such a dominating factor in business relations that possible economies have often been put aside as being of little importance. During the present generation, however, the growing tendency toward combinations and consolidations of various enterprises is evidence that the idea of entirely independent operation of an enterprise is giving way to economy of operation.

Management of public utilities is an excellent example of this tendency. Even companies competing for business in certain territories have arrived at working agreements that have resulted in advantages to all concerned. Interchange of power from one system to another, in order to improve the load factor in both systems, is common practice. Cases also exist where central stations use the excess power from industrial power plants and also use by-product fuel. It would seem that such working agreements should, if properly planned, result in economy to the community and increased dividends to the contracting companies.

Little progress, however, seems to have been made toward combining the power interests of manufacturing districts in such a way as to secure the services of the various plants in the most economical way. It is true that manufacturing districts have been built up having one plant to serve the entire district with power, light, heat, water and steam, but comparatively little has been accomplished toward establishing a working agreement

among the various power plants of a district, by which the most economical distribution of load and services, as well as of by-product fuels, has been established on an operating basis.

From an engineering standpoint, the problem, though somewhat complicated, is not difficult. The great obstacle in the way is the difficulty in getting different manufacturing companies who own their own service plants to agree to a working basis which would naturally take their plants out of their direct control and put them into the hands of a separate organization. Independence is, of course, a valuable condition, but we are inclined to think that the economy gained would, in many cases, be worth more than the independence lost. At least, the manufacturers in a district that could be served by what would virtually be a restricted public service plant, should know what their independence is costing them and a survey such as is reported in this issue by Mr. Gaylord would be of service in this connection.

Off Duty

Twice, during the past month, the world has been startled by the news of the accomplishment of an unusually difficult feat in aviation; first the east to west crossing of the Atlantic by the German airplane, Bremen and second, the flight over the north pole by Wilkins. Both of these flights required courage and daring to an extraordinary degree and the admiration of the world goes out to those who made them. The flight over the North Atlantic, particularly, was a trying one and that the fliers succeeded in reaching the American side at all was a matter of luck, subject largely to the laws of possibility and chance.

Realizing this, many people wonder why such men, to say nothing of women, needlessly risk their perfectly good lives in feats which have so little practical value. Why do they do it? What good will come of it? Of what practical significance are such feats of daring?

Questions such as these have a strange familiarity—perhaps, particularly, if you pursue a hobby, you have even been asked such questions yourself. "Why do you spend so much money on amateur photography? What good does your tinkering with radio equipment do you?" Usually they are asked by the type of person who wonders why Columbus ever went to the inconvenience of discovering America, or why Irvine and Mallory went to their deaths in attempting to climb Mt. Everest.

To those who ask these questions, those practically-minded souls whose view extends only to things which yield a direct monetary return, there is, of course, no answer. But to others there is an answer: because of the tremendous satisfaction that comes from successfully accomplishing an extremely dangerous or difficult thing. There is a fascination in doing things ordinary mortals cannot do. A selfish spirit, perhaps, but often it leads to great practical results. An excellent example is had in amateur radio.

There is in this land, or rather throughout the world, a small group of people who study hard and who, after working all day, sit up late, night after night, listening to faint whistling sounds in telephone receivers clamped to their ears. Others, occasionally having an opportunity of seeing these people at their strange pastime, wonder what it is all about. They are told that these people are radio amateurs and that they are communicating with others similarly disposed.

Radio! Well, that's different. Everybody admits that radio affords a great deal of pleasure when the music is good or the programs otherwise interesting, but what on earth can be the satisfaction in straining one's ears listening to endless faint little squeaks?

The satisfaction in this case is in the extremely difficult. Human standards are still such that it is considered marvelous for one person to sit in his own home and communicate with a fellow amateur across the continent or halfway around the world; and to be able to do this with equipment built with his own hands is the power of the radio amateur.

It is difficult. The ordinary mortal cannot do it. When told about it, he is astonished but he can never realize the intense satisfaction that comes in doing it; and the only thing that makes it possible is the spirit or the desire of accomplishing the impossible.

In 1913, when avaricious commercial and governmental interests began to realize the possibilities of radio, the "useless" waves below 200 meters were relegated to the use of the amateur. Nobody had ever been able to communicate successfully on these wave lengths, so the commercial interests lost nothing in disposing of them to the amateur.

Although disappointed, the amateur was not discouraged and set about to use these waves—he tried to do something nobody else had been able to do. That he succeeded is putting it mildly. He not only succeeded, but developed the "useless" waves to an extent that the commercial world never dreamed of. With power less than that taken by an ordinary lamp, the amateur communicated over distance which commercial stations couldn't do with hundreds of kilowatts!

The case of the extremely dangerous is somewhat different. Whether the world or the human race will benefit greatly by the successful ascent of Mt. Everest is a question which nobody, not even those who tried three times and failed, would care to answer, but no answer is necessary. The question is superfluous. The important thing is that men will try to climb to the top of the world's highest peak, again and again, until finally somebody will succeed. And to that person will come the same exalted satisfaction that was Peary's when he first stood at 90 deg. latitude, north, or Lindbergh's when he landed the Spirit of St. Louis at Paris just one year ago.

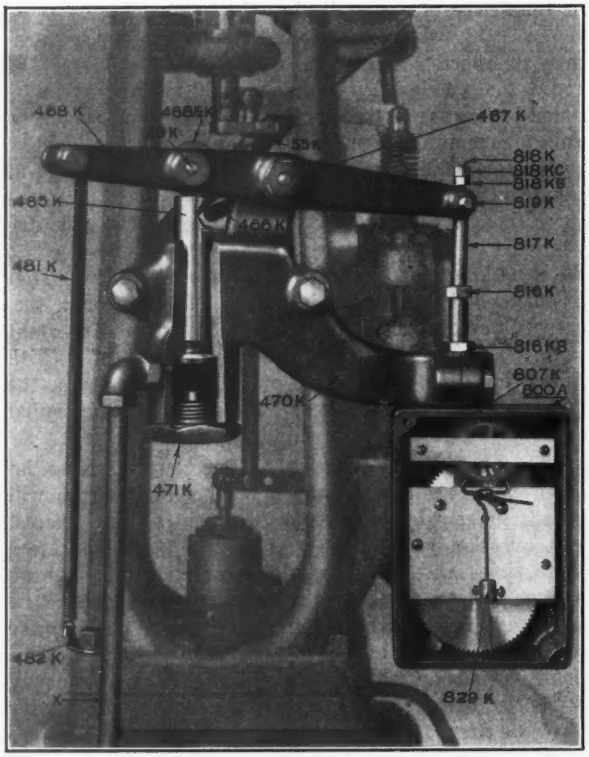
The nature of the task makes little difference. Whether it is the scaling of Mt. Everest in the far off Himalayas or the climbing of the highest hill near one's home or in the making of a better photograph or flying across the Atlantic, the spirit which leads men (and women) to do these things is the same in all cases. It is *the spirit of accomplishment*.

SEVENTY-FIVE million gallons of water a day is pumped from deep-rock wells for use in cities and villages in Illinois, according to an estimate made by the State Water Survey. This amount includes the water pumped from private wells.

POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS

Woodward Mechanical Timer for Hydraulic Governors

AS AN IMPROVEMENT on the oil dashpot, which has been in use by the Woodward Governor Co., Rockford, Ill., since the development of its first automatic hydraulic governor in 1920, a mechanical timer for these governors has been developed. This timer is shown in the accompanying illustration.



NEW MECHANICAL TIMER FOR BRINGING A WATER WHEEL UP TO SYNCHRONOUS SPEED AUTOMATICALLY

The function of both the mechanical timer and the oil dashpot is to produce the starting characteristics required for bringing a water wheel up to synchronous speed automatically at a rate of speed which will permit automatic synchronization and connection of the unit to the line. Oil dashpots, as noted before, have been in use since 1920 and in the main have proved satisfactory. In plants in which the temperature variation was extreme, however, changes in the viscosity of the oil resulted in erratic operation. The mechanical timer is so designed that it is not affected by such temperature variations and is intended to eliminate trouble arising from this source. The mechanical timer is now standard equipment on all Woodward governors and, where required, can be installed on any existing automatic unit.

Unit Air Conditioner for Small Industries

FOR SOME TIME, air conditioning engineers have been faced with the problem of providing adequate conditioning equipment for the small manufacturer. His materials are no less influenced by varying weather and seasonal conditions than those of the manufacturer engaged in large scale production, yet in many small industries the initial investment in a system to create and control atmospheric conditions has proved prohibitive. To make manufactured weather available to any manufacturer whose materials or processes are affected by varying atmospheric conditions, Carrier Engineering Corp., Newark, N. J., has recently placed on the market the Carrier unit air conditioner shown in the accompanying illustration. This unit does not supersede the standard Carrier central station system, but is designed to complement it and to meet the requirements of small industries in which conditions of physical arrangement, initial investment and similar factors may present obstacles to the installation of larger equipment.

LEFT—MANUFACTURING WEATHER BY PUSHING A BUTTON. RIGHT—CONSTRUCTION DETAILS OF THE UNIT AIR CONDITIONER

Reference to the illustration shows clearly the operation of the new unit air conditioner. At the bottom is

a constant level water reservoir communicating with an inner reservoir to which the water may be admitted or cut off by automatic control. From the inner reservoir the water is drawn centrifugally into the water Centrijector. This device consists of a hollow tube rotated by the motor above and carrying six radial pipes with a Carrier spray nozzle affixed to the end of each pipe. Centrifugal action caused by the rotation of the device discharges the water from the nozzle in such a way that the reaction of the discharging water aids the rotation and creates a finely atomized spray across the stream of entering air.

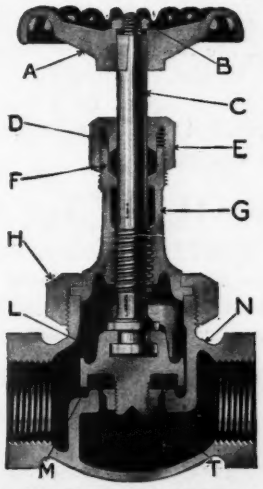
Air drawn from the room or from a connection leading outdoors enters at the bottom and comes in contact with the spray, which is intended to saturate the air completely at the temperature of the spray water. Automatic control of temperature and quantity of water sprayed from the Centrijector is provided. Above this unit and driven by the same motor is a specially designed centrifugal fan to draw the air vertically upward and discharge it at full pressure into the upper part of the cabinet. Here it passes to the eliminators, designed to allow free passage of air but to obstruct the passage of all free unevaporated water carried from the spray chamber.

The air then passes through the Aerofin heater, where it is heated to the desired point above the temperature of saturation. Steam supply to the heater is controlled automatically, thus controlling the temperature of the air delivered. Air passes out through openings on any or all sides of the cabinet.

The unit is enclosed in a cabinet 7 ft. 8 in. high, occupying a floor space 2 ft. 6 in. by 2 ft. 8 in. The casing is of die-stamped and welded steel plate finished in green baked enamel. Removable panels are provided on opposite sides of the cabinet for convenient access. The unit is designed to deliver 2500 c.f.m. of conditioned air, which is stated to be sufficient to provide a complete change of air each 10 min. in a room 25 ft. by 100 ft. by 10 ft. The unit is designed to spray 27 gal. of water per minute at a pressure of 40 lb. per sq. in. and to saturate the air passing through the unit at any temperature over a wide range. A single, 1-hp., totally-enclosed marine motor is installed to drive the fan and the Centrijector. The unit is described and all its parts are illustrated in an attractive 16-page bulletin recently issued by the manufacturer.

Vulcodisc Valve Designed for General Service Up to 150 Lb. Pressure

For service under pressures up to 150 lb. per sq. in. on lines carrying steam, water, gas, air, or oil, the new Vulcodisc valve, shown in the accompanying illustration, has been developed. The principal feature of interest in this valve is the disc itself. This is designed to eliminate sticking, warping or disintegration under heat or pressure. The disc is composed of selected long fibre asbestos, bound with a composition and molded, compressed and vulcanized under high pressure, the entire process being designed to make it tough and dense, yet sufficiently resilient to give perfect seating contact. In addition to this, the disc holder is of the slip disc type, to eliminate the use of a lock nut for holding the disc to the stem head. This is intended to permit quick and easy replacement of the disc. Valve bodies are of a high grade steam bronze composition and are designed with a liberal safety factor. The body is of symmetrical oval design with easy curves and rounded corners to reduce friction to the minimum. Valves are packed with an asbestos

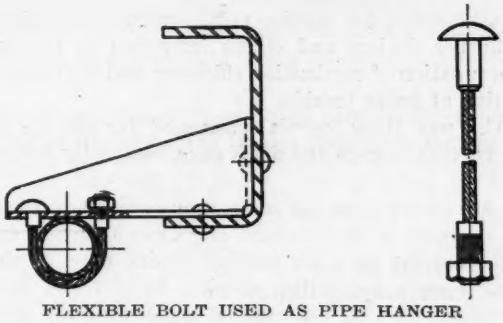


CROSS SECTION THROUGH VULCODISC VALVE SHOWING CONSTRUCTION OF SLIP DISC HOLDER

ring packing and are designed so that they can be repacked while in service. They are made by the D. T. Williams Valve Co., Cincinnati, O., in sizes from ¼ in. to 3 in. and in various types, such as globe and angle stop valves, horizontal and angle check valves and angle and globe radiator valves.

American Cable Company Develops a Flexible Bolt

Through the development of the preformed type of wire rope, designed to make possible the attachment of fittings by the processing method and compel the



FLEXIBLE BOLT USED AS PIPE HANGER

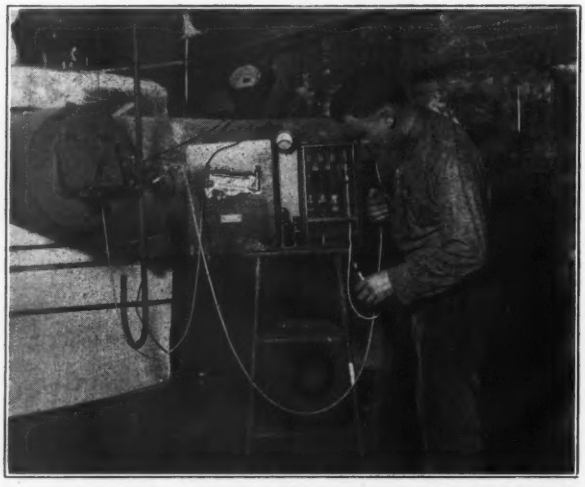
fitting to become an integral part of the rope, the American Cable Co. has recently perfected the Tru-Lay-Tru-Loc flexible bolt illustrated by the accompanying line drawing.

These new bolts are finding application as auxiliary hangers for power shafts, suspension brackets for overhead steam or water piping, shackle bolts for temporary wall boxes, for scaffolding and tackle, on various parts of machinery and in other places where semi-flexible connections are necessary.

Principle on which the new flexible bolt depends is that of the preformed type of wire rope. Preforming wires and strands to the exact helical shape they must assume in the completed rope results in a cable that does not require seizing but may be cut like a rod. This type of rope permits a close fitting attachment to be slipped over the unseized end of the rope and to be processed so that the steel of the fitting flows into the interstices of the rope and thus becomes practically an integral part thereof. Naturally such fittings can be threaded for a nut or capped for a head. The flexible bolt which has resulted from these developments is available in varying lengths.

New Hays Test Set

IMPROVED PORTABLE combustion test set of unique design has just been placed upon the market by The Hays Corporation, Michigan City, Indiana. The idea has been to offer a simple and convenient case



NEW PORTABLE TEST SET IN USE TO DETERMINE CONDITIONS IN HEATING BOILER

of instruments for service men, combustion engineers, oil burner dealers and others interested in the quick determination of combustion efficiency and the cause and location of boiler trouble.

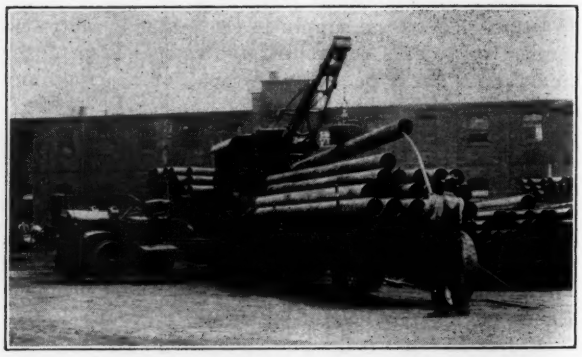
This new Hays test set consists of flue gas analyzer, flue gas thermo-gage and draft gage, compactly arranged in an oak carrying case. When the door and top of the case are swung open the instruments are ready for use. The analyzer is the standard Hays gas analyzer, either single-chamber style for carbon dioxide only, or three-chamber style for carbon dioxide, oxygen and carbon monoxide. A CO_2 test can be made with the instrument in 30 sec. and a complete determination in less than 4 min., it is stated. The analyzer may be removed from the carrying case and hung on a nail driven in the wall if it is desired to make a draft test at one point and a flue gas analysis at another point. The draft gage, which is mounted on the inside of the door, is of the inclined tube type with a micrometer screw for levelling.

The scale is movable for convenience in setting the zero opposite the end of the oil column and a needle valve is provided to lock the oil in the oil well while the set is being transported. The scale has a range of one-half inch water column but an auxiliary spirit level can be added to increase the range to one inch, the scale reading to be multiplied by two when the auxiliary level is employed. The thermo-gage is a small portable indicating pyrometer with the necessary lead wire and special alloy thermo-couple. This instrument has a pointer which indicates the temperature at the tip of the thermo-couple. For flue gas a range of 75 deg. to 1200 deg. F. is recommended but a 75 deg. to 2500 deg. F. range can also be supplied if higher temperatures are to be measured. As an alternative for the thermo-gage a metal armored thermometer, range 100 deg. to 950 deg. F., can be supplied.

The case measures only 6½ in. by 11 in. by 17 in. high and can be slipped into an automobile or underneath the seat of a train. The total weight is less than 20 lb.

Handling Pipe with Magnets

UNLOADING, stacking, rehandling and loading of pipe by the East Ohio Gas Co., Cleveland, Ohio, are all performed with a Universal crane mounted on a 5-t. White truck. Formerly this crane was used with a hook block and sling for this work, but recently this



FIVE-TON TRUCK CRANE EQUIPPED WITH MAGNET HANDLING LARGE PIPE

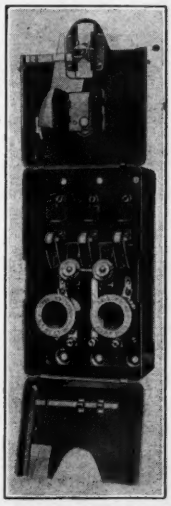
was changed by the installation on the crane of a 22-in., 230-v. pipe type of magnet. This unit is shown in operation in the accompanying illustration. The gas company states that by its use a saving of 60 per cent in time has been effected, besides the elimination of the labor of two men on pipe up to 4 in. and four men on 6 to 8-in. pipe. Mobile crane units of this type are built by the Universal Crane Co., Cleveland, Ohio, and suitable magnets for such work are supplied by the Electric Controller & Magnet Co., also of Cleveland.

Across-the-Line Starter Has Roller Contacts

CUTLER-HAMMER MFG. CO. of Milwaukee, Wisconsin, has just announced a new manual across-the-line a.c. motor starter known as type CH-9115. Designed to meet the need for an inexpensive manual starter, it includes such outstanding advantages as overload cutouts giving complete motor protection; cadmium plated, double break, roller type contacts; and small

size, safety, dust-proof enclosing case. The roller type contacts seem to be the forerunner of an unusual trend in motor control design. They are of the double break type, cadmium plated, and by breaking the arc in two places, give several times the life of ordinary contacts. In addition, the contact rollers turn after each operation to present a new contact surface for the next operation.

Complete motor protection is obtained during both the starting and running periods. The thermal overload cutouts provide the necessary time interval to take care of starting inrushes without shutting down the motor.



THREE-POLE MANUAL MOTOR STARTER. UPPER AND LOWER HALVES OF COVER OPEN

The starter is quite small and compact; the enclosing case is dustproof and the cover is in two parts. This permits opening the lower section only, for replacing fusible links in the thermal overload cutouts. The cover can be opened only when the starter is in the "off" position and all current carrying parts are "dead". Installation can be made without removing the panel from the case. All parts are easily accessible for quick inspection. This starter is applicable for use with fans, pumps, textile machinery, small machine tools, etc.

Refractory Gun Designed to Do Its Own Mixing

ANNOUNCEMENT is made of the Esso refractory gun for the maintenance of furnace linings, boiler settings, and similar refractory surfaces. The new gun is designed to build up a refractory wall ½ in. to 1½ in. thick, to mix its own cement mechanically, to operate on air pressures as low as 30 lb., to be operated by one man and to spray 20 gal. with one filling.

Each gun is fed by a 20-gal. brazed tank equipped with an adjustable reducing valve suitable for the air pressure with which the gun is to be used. Two interchangeable nozzles—one short nozzle for places easily reached and a long one for more difficult locations—are also standard equipment. Air and cement reach the nozzles through 25-ft. lengths of hose attached to the storage tank, and both air and cement are regulated at the gun head by two valves. By varying the amount of air and material, the density of the spray is easily controlled. When through spraying, the operator closes the cement valve, leaving the air on to clean the nozzle ready for the next time. Cement left in the hose can be forced back into the tank by releasing the pressure on the tank with the bleeder valve and bypassing the air pressure into the cement hose by placing a finger over the nozzle. The cement valve on the gun is opened again for this operation, and when the hose has been cleared, the valve at the cement outlet on the tank can be closed to retain the cement in the storage chamber.

Left-over cement can be stored until needed at some future date and then remixed ready for application right in the tank. The mechanical mixing of the ingredients is done in the tank by air. To do this the air line is connected to the cement outlet, the bleeder valve

NEW REFRACTORY GUN, WITH NOZZLES AND HOSE

is opened and the air is admitted through the valve at the base of the tank. The tank is designed so that, as the air rushes through, it sets up a swirling, mixing movement before it escapes at the top.

Fittings and the nozzles for this gun, a product of S. Obermayer Co., Chicago, Ill., are made of brass and the steel tank has a coating of brass to protect it. A pressure gage and an adjustable safety valve are included in the standard equipment and are placed on top of the tank.

IOWA RAILWAY & LIGHT CORP., Cedar Rapids, Iowa, has applied to the state for permission to construct a hydroelectric plant on the Cedar River, Cedar County, near Rochester, Ia., to have a total capacity of about 10,000 hp. Isaac B. Smith is president of the company.

WHEN A SUBORDINATE makes a suggestion, it shows that he is thinking of his work.

Large Transformer Shipped to Pacific Coast in Nitrogen

SHIPMENT of a 25,000-kv.a., 110,000-v., 3-phase, 60-cycle transformer from the Sharon, Pa., works of the Westinghouse Electric and Manufacturing Co., to Oakland, Cal., was accomplished recently in an unusual way. This transformer, instead of being shipped completely assembled in oil, was shipped in an atmosphere of nitrogen under pressure. The use of an atmosphere of nitrogen above the oil of power transformers while they are in service has become a well established practice in the last few years. Nitrogen keeps the oil in prime condition by keeping the oxygen away from its surface and secondly, it provides a gas cushion above the oil to absorb the force of any sudden rise of pressure.

In the shipment of the transformer referred to here, nitrogen was used in a different manner, since no oil was shipped. By the use of nitrogen, the usual drying out process at the receiving end was avoided and the shipping weight reduced 65,000 lb. In this particular

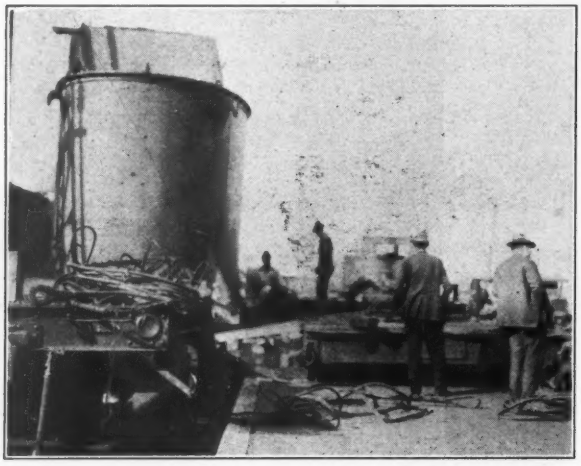


FIG. 1. UNLOADING THE TRANSFORMER AT OAKLAND

case the transformer could not have been handled at the receiving end if the additional weight of oil had been present. Had it been shipped without oil and without the use of nitrogen, a drying out process in Oakland would have been absolutely necessary, involving considerable delay and expense.

The unit was purchased by the Great Western Power Company at Oakland, Cal., where it is now installed in the Oakland Substation of the company. Before the transformer was shipped, it was thoroughly dried and tested. The cover was bolted in place and dry nitrogen was blown through the tank until the oxygen content of the gas in the tank was reduced to 1 per cent. Additional nitrogen was then introduced until the pressure inside the case amounted to 2.95 lb. per sq. in. at 15 deg. C. By the use of this initial pressure in the tank, it was expected that the transformer could be shipped without fear of the leakage of any air, or moisture, from the outside into the tank, any slight leaks occurring being in the opposite direction because of the pressure. As an additional precaution, a bag of calcium chloride was placed in the tank with the idea of taking up moisture if any unexpected leak did occur and also to give an indication to the men who opened the transformer at the receiving end as to whether any moisture had entered the tank.

The transformer was shipped from Sharon on Dec. 30, 1927, and received in Oakland on Jan. 20. Upon its receipt at Oakland, it was transported by truck to the Substation and was there given a test to show the

FIG. 2. VIEW INSIDE THE SUBSTATION WHEN THE TRANSFORMER WAS TAKEN OUT FOR INSPECTION

condition of the gas in the tank. The pressure in the tank was found to be 1½ lb. at a temperature of 15 deg. C. The oxygen content was 1.8 per cent. The tank was then opened and the calcium chloride was found to be perfectly dry. It was, therefore, decided that the shipment had been successful and the transformer was filled with dry oil and placed in service.

ACCORDING TO a survey made by the United States Bureau of Mines, Department of Commerce, there were 1155 natural gasoline plants in the U. S. on January 1, 1928. In addition there was one small plant in Alaska. Of the total number of plants, 1060 or 92 per cent were in operation on January 1, leaving 95 or 8 per cent inoperative. The total number of plants had an indicated capacity of 8,048,000 gal. a day. The results of this survey are given in Information Circular 6062, "Natural Gasoline Plants in U. S.", by G. R. Hopkins and E. M. Seeley, copies of which may be obtained from the U. S. Bureau of Mines, Department of Commerce, Washington, D. C.

TODAY ELECTRICITY is used so widely that it plays a part in the production, manufacture and distribution of nearly every commodity. It has been estimated that there are 65,000 uses for electricity.

News Notes

THE FOXBORO CO., INC., Foxboro, Mass., has established a branch office at 2104 Magnolia Bldg., Dallas, Texas. J. B. McMahon, district manager, is in charge assisted by R. L. Mallory and C. L. Bryan.

BROWN INSTRUMENT CO. has secured larger quarters for its Pacific Coast branch at 420 Westinghouse Electric Bldg., 420 San Pedro St., Los Angeles, Calif., in charge of Stanley F. Godfrey, manager.

PEABODY ENGINEERING CORP., 110 E. 42nd St., New York City, announces that R. T. Forbes, 141 Milk Street, Boston, Mass., of the Green Fuel Economizer Co., is also representing the former company in New England and Northern New York.

GIFFORD-WOOD CONSTRUCTION CO., Graybar Bldg., Lexington at 43rd St., New York City, has absorbed the Warford Construction Co. of Aurora, Ill. These companies have been associated with the Gifford-Wood Co. but with reorganization, the Gifford-Wood Construction Co. will cover the entire territory from its main office with a branch office, 565 W. Washington St., Chicago, Ill., in charge of W. H. Warford, former president of the Warford Construction Co.

BY ARRANGEMENT between J. H. Williams & Co., Buffalo, N. Y., and Husky Wrench Company, Milwaukee, Wis., two combinations of wrench sets, using products of both companies, have recently been placed on the market.

W. G. OWEN, formerly sales manager of the Haws Refractories Co., Johnstown, Pa., has joined the sales force of the General Refractories Co., Philadelphia, Pa.

OFFICERS of the Columbus McKinnon Chain Co. of Tonawanda, N. Y., have recently announced the purchase by their company of the chain block electric hoist crane division of The Chisholm-Moore Mfg. Co., Cleveland, O. A new corporation has been organized to take over the foundry division of the Chisholm-Moore plant and will be known as the Chisholm-Moore Malleable Iron Co. S. H. Moore, president and founder of The Chisholm-Moore Mfg. Co., will continue to be active and the personnel of this company will remain unchanged.

WILLIAM ROBERT QUINN, Pacific Coast representative of Combustion Engineering Corp., died suddenly of heart disease in New York on April 12. For several years Mr. Quinn has been a resident of San Francisco but was in New York on a business trip at the time of his death. He was president of the Quinn Oil Burner and Torch Co. until 1922, when it was purchased by Combustion Engineering Corp. He then became manager of the Fuel Oil Burning Equipment department of the latter company and later went to San Francisco as Pacific Coast representative.

CONSUMERS POWER CO., Jackson, Mich., is completing plans for the first unit of a new steam-operated electric-generating plant on Wealthy St., Grand Rapids, Mich., adjoining a present station at that location. The new plant will have an initial capacity of 26,600 hp., consisting of turbo-generator, condenser, two boilers to operate at a pressure of 400 lb. per sq. in. with pumping units and auxiliary apparatus. It will double the capacity of the present plant which has a rating of about 22,000 kw. The company proposes to use this same site for additional units until an ultimate output of about 260,000 hp. is developed. A proposed hydro-electric power plant on the Muskegon River, recently announced, will be held in temporary abeyance until the steam power project has matured. The entire cost of the Grand Rapids plant is reported in excess of $2,000,000. Extensions will also be made in transmission lines throughout this district. Charles W. Tippy is vice-president and general manager.

AFTER THREE WEEKS of investigation into the cause of the St. Francis Dam disaster, the coroner's jury of Los Angeles reached a verdict that the geological formation was not suited to serve as the foundation of a great dam. No criminal negligence was found but the Los Angeles Bureau of Power and Water and its chief engineer are charged with the chief responsibility.

ROLLER BEARING CO. of America, which has been located in Newark, N. J., since 1919 has just purchased the large plant of the Mercer Motor Car Co., in Trenton, N. J.

C. P. POTTER, engineer in charge of large motor and transformer divisions of the Wagner Electric Corp., St. Louis, Mo., was elected chairman of the St. Louis section of the A. I. E. E., in recognition of his many years of activity in the organization.

AMERICAN FLUID MOTORS CO., Philadelphia, Pa., has appointed Harry H. Leathers, 80 Federal St., Boston, Mass., as its New England agent.

L. J. WING MFG. CO. announces the removal of its general offices to 154 West 14th St., New York, N. Y.

MAXIM SILENCER CO., Hartford, Conn., has recently placed on the market a new model Maxim Silencer, model FG, designed for use on four-cycle Diesel and gasoline engine exhausts. This is designed to be smaller and lighter than previous models for this use and is built so that the entire silencing unit can be withdrawn with the inlet head and easily cleaned.

CLIMAX ENGINEERING CO., Clinton, Ia., is placing on the market a new automatic spark control for use on its heavy duty industrial engines. This control operates from the suction in the intake manifold, depending on the variation in pressure in the manifold.

REPRESENTATIVES of the leading manufacturers of wrought iron in various parts of the country met at the Duquesne Club, Pittsburgh, Pa., on April 5 and formed the Wrought Iron Research Association, the principal object of which is to gather and disseminate information about this metal. L. M. Johnston, vice president of A. M. Byers Co., was elected president and Snowden Samuel of American Swedo Iron Co. secretary-treasurer of the organization. Headquarters will be in Pittsburgh, Pa.

CONSTRUCTION WORK on the addition to the Harrah steam plant of the Oklahoma Gas & Electric Co. near Oklahoma City, which will provide additional generating capacity of 30,000 kw., is progressing satisfactorily, according to H. W. Fuller, vice-president in charge of construction of Byllesby Engineering & Management

Corp., Chicago. Practically all of the steel work for the turbine room has been erected and brick and concrete work on the boiler room section is proceeding satisfactorily. The new unit will be served with steam by two boilers of 250,000 lb. per hour capacity each, fired by pulverized coal. This is the third unit at Harrah Station and it will give the station a total capacity of 65,000 kw.

THE ATOMIZED FUEL CORP., Ft. Dodge, Iowa, has purchased a site southeast of the city for construction of its plant for the manufacture of processed coal, W. G. Coe, Des Moines, president of the concern, announced recently. The plant will be erected from design by the Pennsylvania Engineering Works of New Castle, Pa., and will produce 100 t. of processed fuel daily.

SAN ANTONIO PUBLIC SERVICE CO., San Antonio, Texas, is planning an addition to the power plant of the Comal Power Co., New Braunfels, Texas. The work will include the installation of a 30,000-kw. Westinghouse turbo-generator with new boilers and auxiliaries. Lignite will be used as fuel and a complete pulverizing plant will be installed to prepare it.

ADAM GSCHWINDT, who has been manager of the Rockford, Ill., Electric Co. since 1913, has been made manager of the Rockford Gas, Light and Coke Co., both subsidiaries of the General Public Service Co. Henry S. Whipple, who is retiring from the gas management office, which he has held since 1890, will remain as chairman of its board of directors.

ACCORDING TO a recent announcement by H. M. Hammond, vice chairman of the Publicity Committee of the second national meeting of the Fuels Division of the American Society of Mechanical Engineers, to be held in Cleveland, Sept. 17 to 20, a comprehensive program is being planned. This will include papers by nationally recognized authorities on production, distribution and utilization of fuel. The General Arrangements Committee, under the chairmanship of Colonel Elliott H. Whitlock, consists of Messrs. A. J. Foley, P. V. Fraser, T. F. Githens, H. K. Kugel, Theodore Maynz, F. H. Vose and John Wolff.

ENDOWMENT of $7,000,000 is sought for the Engineering Foundation and the Engineering Societies Library, it is announced by the Board of Trustees of the United Engineering Society, representing the national societies of civil, mining and metallurgical, mechanical and electrical engineers. One fund of $5,000,000 will be applied to the research projects of the Foundation and a second fund of $2,000,000 to the maintenance of the Library. It is also announced that Herbert Hoover has accepted appointment to the Endowment Committee, of which Col. Edward A. Simmons is chairman. Further information can be obtained from the Engineering Foundation, 29 W. 39th St., New York, N. Y.

CANADIAN STEEL AND POWER SHOW will be held at the University of Toronto Arena, Toronto, Canada, from September 4 to 7, 1928. A corporation has been created to conduct this show without profit to its members. The president is Robert McLaren, 150 Dovercourt Rd., and the secretary is Campbell Bradshaw, 24 Front St. West, Toronto, Ont. Co-operating again this year will be the Canadian Section, American Welding Society, Engineers' Mutual Benefit Fund, Canadian Engineering Standards Association, Industrial Accident Prevention Associations and Montreal Chapter, American Society for Steel Treating.

NATIONAL ELECTRIC LIGHT ASSOCIATION will hold its 51st Annual Convention and Exhibition from June 4 to 8, 1928, at the Million Dollar Pier, Atlantic City, N. J. Program of papers to be presented at the sessions will be announced later.

Books and Catalogs

STANDARD HANDBOOK OF STEEL CONSTRUCTION. Published by American Institute of Steel Construction, Inc., 285 Madison Ave., New York City; 384 pages; price, $1.50.

Contained in the 384 pages of text are data indispensable to the designer and specification writer. The contents of the book include the A. I. S. C. Standard Specifications for Construction Steel for Buildings, Standard Specification for Fire-Proofing Structural Steel Buildings and the Code of Standard Practice. There is also a large amount of additional information previously unobtainable in printed form or obtainable only from widely scattered sources and data regarding the new shapes recently produced by rolling mills is complete up to date of issue. The book is divided into four parts and includes a comprehensive alphabetical index.

JOINT WIPING AND LEAD WORK. By William Hutton. Scientific Book Corporation, 15 E. 26th St., New York; 12 chapters, 79 pages and index; price, $1.00.

Practically written and profusely illustrated with actual photographs which are in effect a moving picture of the process, this book gives detailed directions for joint wiping on lead, copper and brass pipes. Hints on how to judge solder, keep tools in condition and carry on various other soldering operations, should make the book of inestimable value to everyone interested in plumbing.

NATIONAL VALVE & MFG. CO., Pittsburgh, Pa., in a recent bulletin gives standards for steel pipe and flanged fittings from 250 to 1350 lb. per sq. in. The standards listed in this booklet were those recently approved by the American Engineering Standards Committee and should be placed in immediate use. All previous issues of standards or dimensions for these pressures are rendered obsolete and should be disposed of to avoid confusion.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 29 W. 39th St., New York City, has recently published the 1927 edition of the Suggested Rules for the Care of Power Boilers, superseding the edition of 1925.

"CHOOSING A HIGH TEMPERATURE CEMENT" is the title of a 24-page illustrated bulletin recently issued by the General Refractories Co., 106 S. 16th St., Philadelphia, Pa.

WALWORTH CO., Box 26, Boston, Mass, has recently issued Walworth Sigma Steel Bulletin No. 6-C describing Walworth Sigma steel flanged fittings made to the tentative American standard. This bulletin supersedes bulletins 6, 6-A and 6-B, which should be destroyed.

Tables of dimensions of fittings are given, the important changes in drilling and sizes being indicated in red on these tables. In making shipment of steel and cast iron flanges drilled to the new standard, Walworth Co. will distinguish new drillings from old standard drillings by applying a splash of green paint to backs and edges of new flanges.

IN THE FIREBOX for Feb. sent out by Plibrico Jointless Firebrick Co., 1800 Kingsbury St., Chicago, Ill., are described features of the boiler plants in the City of Los Angeles and City of Honolulu steamships plying between Los Angeles and Hawaii. Other articles tell of the equipment in the plant of the Otis Building, Chicago, and its operating costs, also of furnace practice in the plants of Thomas A. Edison, Inc., at West Orange, N. J., and of Itasca Paper Co. at Grand Rapids, Minn.

THE HARTFORD STEAM BOILER INSPECTION & INSURANCE CO., Hartford, Conn., has just issued The Boiler Book, a collection of data for use in design and installation of boilers and other pressure vessels. This is the second edition and is compiled by H. E. Dart, assistant secretary. Discussion is given of design of the various types of joints, methods of staying, allowable working pressures, design of furnaces and safety valves and other data of use to engineers. Price of the book is $1.00.

IN A DISCUSSION on Cutting the Cost of Manufacturing, published in pamphlet form by John D. Hamilton, Lexington Bldg., Baltimore, Md., are brought out the ways in which power and steam requirements of an industrial plant may be related or balanced so as to minimize the combined cost of the two and reduce the cost of the manufactured product. Illustrations are given of substantial savings resulting from this method.

POWER PLANT ECONOMY CO., St. Louis, Mo., in a 4-page illustrated folder describes Super-refracto baffles for horizontal water tube boilers. These are tile-monolith units installed in such a way that a clearance space is formed around the tube so that it can be withdrawn without disturbing the baffle.

FROM THE Pipe Saver Corp. of America, Carthage, N. Y., comes a folder describing the use and advantages of pipe-savers at coupling pipe joints to prevent corrosion and erosion of the ends of the pipe within the coupling. Results are given of a 3½-yr. test under working conditions.

MONITOR CONTROLLER CO., Baltimore, Md., in Bulletin 112, describes thermaload starters, designed to give protection to polyphase and single-phase motors in starting and running, at the same time permitting full-voltage, full-current and full-torque starting.

POLYPHASE induction motors, types AR and ARY, with either sleeve or tapered roller bearings, are completely described and illustrated in bulletin 1118-E recently issued by Allis-Chalmers Mfg. Co., Milwaukee, Wis.

INGERSOLL-RAND CO., 11 Broadway, New York, N. Y., has published a 44-page bulletin describing class ER and FR compressors and vacuum pumps. These are small and intermediate size machines of the straight line type; they are built as single-stage, two-stage or three-stage units for handling either air or gas. The single-stage units are made in sizes having piston displacements of from 28 to 1084 c.f.m. at discharge pressure of 15 to 160 lb. per sq. in. The multi-stage units are for discharge pressures up to 1750 lb.

GREENE, TWEED CO., 109 Duane St., New York City, in a 4-page folder describes Style C packing, a rod packing that withstands caustic soda and similar chemicals.

HAGAN CORP., Pittsburgh, Pa., has just issued bulletin 104 describing the Hagan system of automatic control of forced draft stoker fired boilers.

AUTOMATIC PUMPS with EC & M control are described in a four-page folder issued by The Electric Controller & Mfg. Co., Cleveland, O.

FILER & STOWELL CO., Milwaukee, Wis., in a 20-page illustrated bulletin, describes various types of hoisting engines.

REPUBLIC FLOW METERS CO., 2240 Diversey Parkway, Chicago, in a recent 28-page illustrated catalog, W-42, describes Republic water meters for all types of central station and industrial applications.

YARNALL-WARING CO., Chestnut Hill, Philadelphia, Pa., in a four-page folder, B-415, gives a list of installations of Yarway blowoff valves made during 1927 for various pressures from 250 to 1350 lb. per sq. in.

CLEVELAND FLUE CLEANER MFG. CO., Cleveland, Ohio, is now manufacturing the Cleveland boiler feed regulator, formerly manufactured by the Cleveland Feed Water Regulator Co., and is issuing a 28-page illustrated bulletin describing and illustrating the device.

MIDWEST AIR FILTERS, INC., Bradford, Pa., has just issued an indexed folder containing in loose-leaf form bulletins describing in detail various applications of Midwest air filters.

NATIONAL FLUE CLEANER CO., INC., Groveville, N. J., is issuing a 4-page folder describing the National soot blower for horizontal return tubular boilers and giving data on the results obtained with these blowers.

AUTOMATIC CONTROL CORP., 9 Neponset St., Worcester, Mass., a subsidiary of Riley Stoker Corp., has issued an eight-page illustrated leaflet describing the Acco electric door operator for elevator doors.

CHICAGO PNEUMATIC TOOL CO., 6 44th St., New York City, has just issued catalog No. 561, describing pneumatic tools and accessories. Various types of riveting hammers are illustrated and described, together with stone drills, rock drills and demolition tools.

REEVES PULLEY CO., Columbus, Indiana, has just issued an entirely new catalog, No. 88, describing and illustrating in detail the new design of Reeves variable speed transmission. The bulletin discusses construction and operating principle, remote and automatic controls and applications of units in various industries.

THE SUPERHEATER CO., 17 E. 42nd St., New York, has just issued a 16-page booklet on Elescooperation giving information about the Elesco superheaters and the service of the Industrial departments of the company. Copies will be sent to anyone interested.

Power Plant Construction News

Ala., Clanton—The Alabama Mills Co., Birmingham, Ala., Clifford J. Durr, president, will install power equipment in a proposed new cotton mill at Clanton, to cost $150,000. Erection will soon begin. Robert & Co., Inc., Bona Allen Building, Atlanta, Ga., are engineers.

Ala., Tuscaloosa—The E-Z Opener Bag Co., Decatur, Ill., has authorized the construction of a one-story power plant, 110 x 120 ft., at its proposed new mill at Tuscaloosa. Entire project is reported to cost in excess of $2,500,000. W. E. Spink, New Orleans, La., is architect.

Ark., Malvern—The International Shoe Co., 1505 Washington Street, St. Louis, Mo., will install power equipment in a proposed canvas fabric mill on local site, entire project to cost more than $100,000 with machinery.

Calif., Holtville—The Board of City Trustees will install a pumping plant in connection with extensions and improvements in the municipal waterworks. Entire project will cost $40,000. The Burns, McDonnell, Smith Engineering Corporation, Western Pacific Building, Los Angeles, is engineer.

Calif., Los Angeles—The Los Angeles Gas & Electric Corporation, South Flower Street, has approved plans for a one-story power substation, 52 x 104 ft., on South Woodlawn Avenue, near Vernon Avenue, to be of automatic type. Plans have been approved also for a one-story addition to power substation at 1337-67 Lawrence Street for increased capacity.

Calif., Richmond—Johns-Manville Co. of California, Inc., 195 New Montgomery Street, San Francisco, manufacturer of pipe covering and other asbestos products, will install power equipment in a proposed new plant at Richmond, entire project to cost more than $1,000,000.

Calif., Santa Clara—The Pacific Mfg. Co., Santa Clara, will build a one-story boiler house at proposed new woodworking plant on local site, entire project to cost $200,000. Company will also install dust-collection system, dust bins, motors and other industrial power equipment. Hamm, Grant & Bruner, Inc., Ferguson Building, Los Angeles, is engineer.

Calif., San Diego—The San Diego Consolidated Gas & Electric Co. has taken out a permit for the construction of a new power plant on West Broadway to cost approximately $450,000.

Fla., Miami—The Roberts & Gretner Properties, Inc., Seybold Building, has filed plans for the construction of a new cold storage and refrigerating plant at N. W. Seventh Avenue and Seventeenth Street, 100 x 225 ft., to cost more than $175,000, with equipment. Brewer & Co., 20 Fifth Avenue, are architects and engineers.

Fla., West Palm Beach—A. S. Andersen, 519 Twenty-eighth Street, West Palm Beach, and associates, are planning the construction of a six-story cold storage and refrigerating plant, 100 x 300 ft., on local site, to cost in excess of $230,000, with machinery.

Ga., Atlanta—Plans are being prepared for construction of a $125,000 power plant for Agnes Scott College, also for $300,000 administration building and a $125,000 chapel.

Ga., Calhoun—The Echota Cotton Mills, Inc., will install power equipment in a proposed new plant addition to cost close to $100,000, with machinery.

Idaho, Pocatello—The Oregon Short Line, operated by the Union Pacific Railway Co., Omaha, Neb., plans extensions and improvements in local steam-operated power plant, including installation of boilers and other equipment, estimated to cost about $100,000. An appropriation has been arranged.

Ill., Chicago—The Commonwealth Edison Co., 72 West Adams Street, has filed plans for a two-story power substation, 42 x 103 ft., at 125-27 North Dearborn Street, to cost about $75,000, with equipment.

Ill., Moline—The Harrington-Seaberg Corporation, Moline, plans installation of power equipment in proposed plant addition for manufacture for fire alarm systems, etc. Project will cost about $80,000.

Ill., Rockford—The Rockford Paper Box Co., Sayre Street, will install power equipment in a new one-story plant unit to cost about $110,000. Plans have been filed.

Ind., Kendallville—The City Council has authorized plans for the construction of an addition to the municipal power plant on Diamond Street, reported to cost more than $50,000 with equipment. Froelich & Emory, Toledo, Trust Building, Toledo, Ohio, are engineers.

Ky., Louisville—The Henry Fischer Packing Co., 1860 Mellwood Avenue, has filed plans for a one-story cold storage and refrigerating plant to cost about $50,000, with equipment.

Mass., Boston—The Boston Ice Co., 110 State Street, Boston, operated by the American Ice Co., Philadelphia, Pa., is completing plans for a one-story ice-manufacturing plant on Dewar Street, Dorchester district, to cost more than $100,000 with machinery. C. L. Weir, Knickerbocker Ice Co., 41 East Forty-second Street, New York, an affiliated organization, is engineer.

Md., Baltimore—The Proctor & Gamble Co., Cincinnati, Ohio, plans construction of a boiler plant in connection with a new factory on 8-acre tract of land at Locust Point, Baltimore, recently acquired. Entire project will cost close to $3,000,000.

Miss, Jackson—The Mississippi Steel & Iron Co., High Street, will install power equipment in a new one-story plant unit reported to cost more than $100,000, with machinery.

Mich., Lansing—Durant Motors, Inc., will install power equipment in a new addition to its automobile manufacturing plant, reported to cost more than $500,000 with machinery.

N. J., Paterson—The Wright Aeronautical Corporation plans the installation of power equipment in proposed new plant units on Lewis Street, reported to cost more than $1,000,000 with machinery.

Ohio, Cincinnati—The Andrew Jergens Co., Spring Grove Avenue, Cincinnati, will install power equipment in a five-story addition to its soap-manufacturing plant, reported to cost about $200,000.

Ohio, Cleveland—The Department of Public Service, City Hall, has plans under way for the construction of a pumping station and filtration plant in Nottingham district, reported to cost more than $300,000. L. A. Quayle, City Hall, is city engineer.

Ore., Astoria—The Northwestern Pulp & Paper Co., care of B. T. McBain, Portland, Ore., mill engineer and manager, will install power equipment in proposed new pulp and paper mill at Astoria, for which superstructure will soon begin; a boiler plant is planned. Entire project will cost in excess of $1,000,000.

Pa., Philadelphia—England, Walton & Co., Inc., Third and Vine Streets, will install power equipment in a new addition to leather tannery on Vine Street.

Pa., Philadelphia—The Nice Ball Bearing Co., Hunting Park Avenue, will install power equipment in a new addition to its plant to cost about $150,000.

R. I., Pawtucket—The Blackstone Valley Gas & Electric Co. has completed plans for a four-story and basement addition to its steam-operated electric generating plant on Tidewater Street, known as Station No. 1, to be 20 x 150 ft., estimated to cost $125,000.

Tenn., Knoxville—The Diamond Ice Co., Cooper Street, plans construction of an ice-manufacturing plant on Sixth Avenue, to be equipped for capacity of 100 tons per day, estimated to cost approximately $130,000.

Texas, Beaumont—The Beaumont Export & Import Co. contemplates the construction of a boiler plant at a proposed new lumber mill in the Vanwormer industrial district, for which site has just been acquired. Entire project will cost close to $80,000.

Texas, Dallas—The Chase Bag Co., 250 West Fifty-seventh Street, New York will install power equipment in a proposed two-story plant at 1109 South Lamar Street, Dallas, estimated to cost about $100,000.

Va., Covington—The Industrial Rayon Corporation, Walford Avenue and West Ninety-eighth Street, Cleveland, Ohio, plans construction of a boiler plant at its proposed local rayon mill; a pumping station is also projected. Entire project will cost more than $2,000,000.

Wash., Aberdeen—The Grays Harbor Railway & Light Co., Aberdeen, is completing plans for an addition to its steam-operated electric generating plant to develop a capacity of 10,000 hp., estimated to cost close to $1,000,000, including improvements in present station, extensions to transmission lines and distributing systems.

Wis., Appleton—The Appleton Coated Paper Co., 1200 North Meade Street, plans the installation of power equipment in a new addition to cost about $125,000. Lockwood, Green & Co., 400 North Michigan Avenue, Chicago, Ill., are architects and engineers.